RODDICKTON MINI-HYDRO DEVELOPMENT

A GUIDE FOR DESIGN AND CONSTRUCTION

A SMALL-SCALE HYDRO DEMONSTRATION PROJECT IN
RENEWABLE ENERGY AND ENERGY CONSERVATION TECHNOLOGY

A JOINT UNDERTAKING BY

THE DEPARTMENT OF ENERGY, MINES AND RESOURCES OF CANADA
AND
NEWFOUNDLAND AND LABRADOR HYDRO CORPORATION

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SYNOPSIS

This report provides a guidance manual for the engineering design, construction methodology and operational considerations of a mini-hydro installation.

From its Special Demonstration Program initiated in 1978, the federal Department of Energy, Mines and Resources contributed a grant of $985,000 to the construction of the 425 kilowatt Roddickton plant, built by Newfoundland and Labrador Hydro at a cost of $1,225,000. The mini-hydro plant in Northern Newfoundland was constructed in the summer and fall of 1980. It went into operation in December, 1980 and officially opened in June 1981.

The federal energy program encourages reduced dependence on oil and the development of renewable energy resources. This project consistent with the energy program was developed to study the potential for small scale hydro to displace high cost diesel fuel for power generation by communities in areas which do not have access to electricity grids. The Roddickton project is interconnected with the existing isolated diesel system and operated by automatic remote control at the diesel plant.

The main part of the report was prepared by staff of Newfoundland and Labrador Hydro. The concept and original layout was initially developed by ShawMont Newfoundland Limited. The staff of the Department of Energy, Mines and Resources provided the Report Summary and editing.

SUMMARY

1. INTRODUCTION

In 1978 Newfoundland and Labrador Hydro Corporation and the Federal Department of Energy, Mines and Resources entered into an agreement to evaluate and demonstrate the potential of small scale hydro developments for isolated communities with diesel generation systems.

The first phase was an engineering evaluation to identify the hydroelectric potential and recommendation of a location for demonstration. The study was carried out by ShawMont Newfoundland Limited. This evaluation concluded that twenty-eight of the forty isolated diesel systems have sites suitable for small scale hydro development. Two of these sites appear to be economic and eleven marginally economic, when viewed from the electric utility perspective. They represent 10 to 25% of the total existing remote diesel generation in Newfoundland and Labrador. Simplified techniques for site selection and energy potential assessment were developed. The evaluation also provided proposals for simplified design, construction, installation and operation of small scale hydro plants at isolated locations and is summarized in Appendix B of this report.

The second phase was the construction, installation and operation of a project at a site selected for demonstration. The Roddickton project was considered to be reasonably representative of the potential sites that are marginally economic and possesses no particularly unusual characteristics. The objectives of the demonstration were:

- to identify simplified construction and installation techniques and to improve design methods;
- to identify environmental considerations;
- to determine the actual cost of a small hydro project and its economic viability.

2. FINDINGS

The following is a brief summary of the findings as described in detail in this report.

2.1 SIMPLIFIED CONSTRUCTION AND INSTALLATION TECHNIQUES

2.1.1 Plant Equipment Package

In the interests of minimizing cost and to facilitate on-site installation, the Tender Specification for the Generating Equipment Package permitted suppliers to quote on an "off the shelf" package. Detailed specification was waived so that standard packages in a pre-fabricated design could be accommodated. In retrospect, specific details of the generating equipment package should have been more closely defined as misunderstandings arose regarding the cost of some items.

The cross-flow Ossberger turbine was seleced as being the most suitable for the site conditions and being likely to result in the lowest installed cost. Invited tenders were made to Canadian suppliers. Award was made to F.W.E. Stapenhorst of Point Claire, Québec as the sole bidder. The package includes speed increaser, synchronous generator with automatic voltage regulator, flywheel, governor, electrical control panel ,draft tube, turbine inlet and butterfly valve. No permanent powerhouse overhead crane or lifting device was included in the design. The unit assembly was simple and, including suppliers' erection supervision and testing, was expected to take no more than two weeks. Due to equipment package late delivery, the erection procedure was affected; it took four weeks to complete the installation.

2.1.2 Civil Design and Construction

i) A rock-filled timber crib dam with upstream face sheeting was selected. It is simple to construct and labour-intensive. The skills required are readily available in the local area. It incorporates spillway and intake allowing less expensive installation.

ii) More than four hundred meters of polyethylene pipes are used for the penstock or pressure conduit installation. The 800 mm nominal diameter pipes were fused and joined in the field in eight days. The pipes are buried. A butterfly valve and a vacuum breaker valve were installed at the intake for draining to prevent possible ice formation during winter shutdowns.

iii) Field construction was accomplished in five months and involved a total of 30,000 manhours. This was made up of 60% by labourers and carpenters, 20% by equipment operators, and 20% by supervisors and management. The 26,000 manhours of the total 30,000 manhours involved local labour and involved maximum of 28 persons during the peak construction period. Only eighteen engineering drawings were required and only one site engineer was employed to modify the design to adapt it to site conditions, thus minimizing engineering design costs.

2.1.3 Telecontrol and Operation

The mini-hydro plant is interconnected with the existing isolated diesel system. The design concept was based on replacement of diesel fuel by generation from a run-of-river hydro plant. The plant is operated to maximize average annual energy by minimizing the spill of water from the limited upstream pondage.

The plant is remotely controlled and operated from the diesel plant. Utilizing a mini-supervisory system, the VHF radio link provides the diesel plant operator with control options of shutting down the unit and raising and lowering the kilowatt output and voltage of the hydro plant. Information on indicated head pond water level, kilowatt output, power factor and voltage is relayed back to the diesel plant. Start up and synchronization of the unit is by manual control only at the hydro plant.

2.2 ENVIRONMENTAL CONSIDERATIONS

Small hydroelectric projects of less than 1 MW are not subject to the extended formal Environmental Assessment processes by Government agencies in Newfoundland and Labrador. The Roddickton project was reviewed under the Water Resources Section of the provincial Consumer Affairs and Environment Act. The Act provides for the protection of the municipal water supply and for review of water quality changes resulting from the construction of the dam and reservoir. Another requirement is for review of the potential impacts on salmon migration and spawning under the Canada Fisheries Act.

Water samples were collected and the local Town Council actively participated in the review. A contigency plan for an alternate water supply was developed by Newfoundland and Labrador Hydro in the event that an unexpected contamination should occur during construction. Newfoundland and Labrador Hydro also decided that, considering the presence of a municipal water supply downstream of the hydro dam, untreated western hemlock wood would be used in the timber crib dam rather than chemically treated preserved wood as was originally proposed.

A fish population and habitat survey carried out showed that Atlantic salmon are unable to migrate up to the plant site. A water release structure capable of maintaining 200 litres/second minimum flow was constructed and federal and provincial inter-departmental co-ordination is ongoing to relate efficient plant operation with acceptable downstream flow requirements.

2.3 ACTUAL COSTS AND ECONOMIC VIABILITY

Completion of the project demonstrated that the small scale hydro project could be built within the anticipated short construction time and with actual costs of $1,225,000 which are reasonably close to the original estimates of $1,095,400. The 425 kW project cost $2,880 per kilowatt to install at end of 1980. The annual capacity factor will be approximately 40%. Total project cost breakdown is: mechanical and electrical equipment and installation 28%; civil structures and installation 53%; project design and management 16%.

In the engineering evaluation of small scale hydro for Newfoundland and Labrador by ShawMont Newfoundland Limited, the economics analysis was made by comparing the estimated cost of the hydro project against the operating cost saving at the diesel generating plant. The evaluation used a discount rate of 12%, an annual escalation rate of 7.5% in diesel fuel prices and a twenty-year analysis period. The conclusion was that two sites had higher present value of fuel displaced than the estimated costs, eleven sites had nearly equal benefits and costs, and fifteen sites had costs far in excess of their benefits. The Roddickton project represents one of the eleven sites judged to be marginally economic.

The average unit energy cost from the Roddickton mini-hydro project is estimated to be 125 mills/kWh assuming 14% discount rate and a 30 year life. The fuel cost for diesel generation at Roddickton in year 1980 is approximately 54 mills/kWh. If one assumes a long-term annual fuel escalation rate of 10%, the discounted levelized unit fuel cost in 127 mills/kWh. Under these assumption project long-term benefits are approximately equal to project long-term costs.

By using either a lower discount rate of 12% or international oil prices, analysis has shown the project would be economically attractive over its life time. It would take 20 years to break even at 12% discount. Economic analysis results are summarized in Appendix C of this report.

3. CONCLUSION

Including the Roddickton project, twenty-eight of the forty isolated diesel systems in Newfoundland and Labrador have sites suitable for small-scale hydro development. Total potential of these hydro sites is very large and is capable, in theory, of supplying the full energy needs of most of the remote diesel systems. Of these twenty-eight sites, thirteen may have economic potential to displace up to 25% of total remote diesel generation but eleven of these sites are likely to be only marginally economic. These thirteen sites represent a possible annual saving of 6.5 million litres of diesel fuel.

The advantages of an economic small scale hydro development include the displacement of oil use by a renewable resource; stable long-term energy costs; operational simplicity and low maintenance; and minimum environmental impact. The main challenge is to reduce high capital costs in order to enchance economics, since there are obvious difficulties in justifying investment in marginally economic projects in the face of uncertain future diesel fuel costs. Severe climatic conditions and the extremely variable streamflow throughout the year must be adeqately considered. High costs of access and for transmission lines and high mobilization costs for construction equipment are characteristic of remote hydro site development.

The Roddickton project demonstration provides an example of the design and construction of a mini-hydro development and illustrates the economic and technical challenges faced by such projects. It has demonstrated generally good experience in simplified construction and installation based upon a particular turbine type. For any future similar project, further attention and consideration should be given to lead time for major equipment package purchases; to the amount and timing of field surveys to confirm site conditions and hydrology; to earlier completion of design details to allow sufficient time to obtain approval from environmental agencies; and to detailed material requirement lists and strict monitoring of equipment delivery dates.

MINI-CENTRALE HYDROÉLECTRIQUE DE RODDICKTON
MANUEL DE DESIGN ET DE CONSTRUCTION

ÉNERGIES RENOUVELABLES ET TECHNIQUES D'ÉCONOMIES D'ÉNERGIE
PROJET DE DÉMONSTRATION D'UNE PETITE CENTRALE HYDROÉLECTRIQUE

PROJET RÉALISÉ EN COMMUN PAR

LE MINISTÈRE DE L'ÉNERGIE, DES MINES ET DES RESSOURCES DU CANADA

ET

LA NEWFOUNDLAND AND LABRADOR HYDRO CORPORATION

SYNOPSIS

Ce rapport donne des indications utiles sur la conception technique, la méthode de construction et les conditions d'exploitation d'une mini-centrale hydroélectrique.

Depuis qu'il a lancé son Programme de démonstrations spéciales en 1978, le ministère fédéral de l'Énergie, des Mines et des Ressources a versé 985 000 $ en subventions pour le financement de la centrale de 425 kilowatts de Roddickton. Cette centrale du Nord de Terre-Neuve a été construite par la Newfoundland and Labrador Hydro à un coût de 1 225 000 $, pendant l'été et l'automne de 1980. Elle est entrée en service en décembre de la même année et a été officiellement inaugurée en juin 1981.

Le programme énergétique du gouvernement fédéral vise notamment à réduire la consommation de pétrole grâce à la mise en valeur de ressources énergétiques renouvelables. Ce projet, qui s'inscrit dans l'esprit du programme énergétique, a été mis sur pied en vue d'étudier la possibilité de construire de petites centrales hydroélectriques pour remplacer des groupes diesel plus coûteux qui sont actuellement utilisés dans des régions non desservies par les réseaux d'électricité. La centrale de Roddickton est couplée au réseau des groupes diesel en milieu isolé et commandée à distance d'une des centrales au diesel.

L'essentiel du rapport a été préparé par des employés de la Newfoundland and Labrador Hydro. La conception et le plan original de la centrale sont l'œuvre de la ShawMont Newfoundland Limited. Le personnel du ministère de l'Énergie, des Mines et des Ressources s'est occupé du résumé et de la révision du rapport.

RÉSUMÉ

1. INTRODUCTION

En 1978, la Newfoundland and Labrador Hydro Corporation et le ministère de l'Énergie, des Mines et des Ressources ont conclu un accord en vue d'évaluer et de démontrer la possibilité d'aménager de petites centrales hydroélectriques dans des collectivités isolées qui produisent actuellement leur électricité au moyen de groupes diesel.

Dans un premier temps, on a procédé à une évaluation technique afin de déterminer la possibilité d'aménager un site en centrale hydroélectrique, puis on a recommandé un site propice à la démonstration. L'étude a été confiée à la ShawMont Newfoundland Limited. Il en est ressorti que vingt-huit des quarante groupes diesel isolés se trouvaient à des endroits qui se prêteraient à la construction de petites centrales hydroélectriques. Deux de ces sites apparaissent rentables et onze semblent présenter une rentabilité marginale, lorsqu'on les considère selon les critères des services d'utilité publique. Ils représentent entre 10 et 25 % de l'ensemble de la production diesel actuellement obtenue en milieu isolé à Terre-Neuve et au Labrador. Les auteurs de l'étude ont mis au point des techniques simplifiées pour la sélection du site et l'évaluation du potentiel hydroélectrique. Ils ont aussi proposé des méthodes simples de conception, de construction, d'installation et d'exploitation de petites centrales hydroélectriques en milieu isolé; leurs suggestions sont exposées succinctement à l'Appendice B du rapport.

La deuxième phase du projet a consisté à construire, à installer et à exploiter une petite centrale à l'endroit qui avait été retenu pour la démonstration. On estimait que le projet de Roddickton était assez bien représentatif des sites à rentabilité marginale et qu'il ne présentait aucune caractéristique exceptionnelle. La démonstration avait pour objectifs:

- de définir des techniques de construction et d'installation simplifiées et d'améliorer les méthodes de conception;
- de déterminer les facteurs environnementaux à considérer;
- de calculer le coût réel et la rentabilité d'une petite centrale hydroélectrique.

2. CONCLUSIONS DU RAPPORT

Voici un bref résumé des conclusions formulées en détails dans le rapport.

2.1 TECHNIQUES DE CONSTRUCTION ET D'INSTALLATION SIMPLIFIÉES

2.1.1 Équipement de la centrale

Dans le but de minimiser les coûts et de faciliter l'assemblage de la centrale sur place, le cahier des charges a été établi de manière à ce que les fournisseurs puissent fixer un prix pour un groupe électrogène "tout fait". On a renoncé à un cahier des charges détaillé, de sorte que les groupes électrogènes normalisés, de type préfabriqué, pouvaient être acceptés. Avec le recul, on se rend compte que certains détails de l'ensemble auraient dû être précisés, car le coût de certains éléments a causé des malentendus.

On a retenu la turbine radiale Ossberger car on a jugé que c'est celle qui s'adapterait le mieux aux conditions observées sur le site et qui entraînerait probablement le plus faible coût après installation. Un appel d'offres a été lancé à des fournisseurs canadiens. Le contrat a été adjugé à F.W.E. Stapenhorst de Pointe-Claire, Québec, le seul soumissionnaire en lice. Le groupe électrogène comprend un démultiplicateur de vitesse, un générateur synchrone à stabilisateur de tension automatique, un volant d'inertie, un régulateur, un panneau de commande électrique, un tube d'aspiration, un collecteur d'admission et une vanne papillon. Le plan ne prévoyait aucun pont roulant ni aucun appareil de levage permanent. L'assemblage était simple, et on prévoyait qu'il ne prendrait pas plus de deux semaines à réaliser, en incluant la supervision et les essais. Toutefois, à cause d'un retard dans la livraison du matériel, il a fallu quatre semaines pour terminer l'installation.

2.1.2 Travaux de génie civil

i) Le choix a été arrêté sur un barrage en enrochements à charpente et à parement amont blindé. Ce type de structure est simple à construire et réclame surtout de la main-d'œuvre. De plus, il est facile de trouver dans la région immédiate des ouvriers compétents. Le barrage comprend un déversoir et une prise d'eau, ce qui diminue les frais d'installation.

ii) Plus de quatre cents mètres de tuyaux de polyéthylène sont utilisés pour l'installation de la conduite forcée. Les tuyaux, qui ont un diamètre nominal de 800 mm, ont été fondus et assemblés sur place en huit jours. Ils sont enfouis. La prise d'eau a été munie d'une vanne papillon et d'une soupape casse-vide pour drainer de façon à prévenir la formation de glace pendant les fermetures d'hiver.

iii) La construction sur place a exigé cinq mois et un total de 30 000 heures-hommes réparties de la façon suivante: ouvrier et charpentiers: 60 %; opérateurs d'équipement: 20 %; supervision et gestion: 20 %. De ce total, 26 000 heures-hommes ont été confiées à de la main-d'œuvre locale; jusqu'à 28 personnes ont été engagées au plus fort des travaux de construction. La construction de la centrale n'a exigé que dix-huit dessins techniques, et un seul ingénieur était sur place pour adapter les plans aux conditions du site; les frais de dessin technique ont donc été limitée.

2.1.3 Télécommande et exploitation

La mini-centrale hydroélectrique est connectée au réseau de groupes diesel isolés actuellement en place. L'idée au départ était de remplacer un groupe diesel par une centrale au fil de l'eau. La centrale est exploitée de manière à maximiser la production annuelle moyenne d'énergie en limitant le plus possible le volume d'eau déchargé du bassin limité situé en amont.

La mini-centrale est controllée à distance du poste de commande de la centrale au diesel. Un mini-système de surveillance par liaison radio T.H.F. permet à l'opérateur de la centrale au diesel d'arrêter le groupe et d'élever ou d'abaisser la puissance et la tension de la centrale hydroélectrique. Les données sur le niveau de la retenue amont, la puissance, le facteur de puissance et la tension sont transmises à la centrale au diesel. Le démarrage et la synchronisation du groupe électrogène se font à la centrale hydroélectrique, par voie manuelle seulement.

2.2 FACTEURS ENVIRONNEMENTAUX À CONSIDÉRER

A Terre-Neuve et au Labrador, les petites centrales hydroélectriques de puissance inférieure à 1 MW ne sont pas soumises à une évaluation environnementale approfondie des organismes gouvernementaux. Le projet de Roddickton a été examiné en vertu de la section sur les ressources hydrauliques de la Consumer Affairs and Environment Act de la province. Cette loi pourvoit à la protection des réserves d'eau municipale et au contrôle des variations de la qualité de l'eau qui résultent de la construction du barrage et du réservoir. En outre, le gouvernement fédéral doit étudier les effets possibles de la construction sur la migration et le frai du saumon en vertu de la Loi sur les pêches.

Des échantillons d'eau sont prélevés et le conseil municipal participe activement à leur analyse. La New foundland and Labrador Hydro a mis sur pied un plan d'urgence qui prévoit le recours à une autre source d'eau au cas où une contamination imprévue surviendrait au cours de la construction. La Newfoundland and Labrador Hydro a également décidé qu'en raison de la présence d'une source d'alimentation en eau municipale en aval du barrage, on utiliserait du bois non traité de pruche de l'Ouest pour la construction du barrage, et non du bois traité chimiquement comme on le proposait au départ.

Une étude des populations et des habitats de poissons a démontré que le saumon de l'Atlantique était incapable de remonter le cours d'eau jusqu'à la centrale. C'est pourquoi on a aussi construit un déversoir capable de maintenir un débit de 200 litres à la seconde. De plus, les ministères compétents des gouvernements fédéral et provincial coordonnent leurs activités de manière à allier une exploitation efficace de la centrale et un écoulement d'eau acceptable en aval.

2.3 COÛTS RÉELS ET RENTABILITÉ

Le projet a démontré que la petite centrale hydroélectrique pouvait être construite dans le court délai imparti et à un coût réel de 1 225 000 $, qui est assez près de l'estimation initiale de 1 095 400 $. Le projet de 425 kW coûte 2 880 $ par kilowatt à installer à la fin de 1980. Le coefficient d'utilisation annuel sera d'environ 40 %. Les coûts du projet se répartissent de la façon suivante: équipement mécanique et électrique, et installation: 28 %; structures du génie civil, et installation: 53 %; conception et gestion du projet: 16 %.

Dans le cadre de son évaluation technique, la ShawMont Newfoundland Limited a exécuté une analyse économique en comparant le coût estimé de la centrale hydroélectrique aux économies de frais d'exploitation pouvant être réalisées à la centrale au diesel. Pour ce faire, elle a utilisé un taux d'escompte de 12 %, supposé un taux annuel d'augmentation des coûts du diesel de 7,5% et étalé ses projections sur une période de vingt ans. Voici ce qu'il en ressort: à deux endroits, la valeur actuelle des économies de diesel est supérieure aux coûts estimés, à onze endroits les rendements et les coûts sont presque égaux et, à quinze endroits, les coûts dépassent de beaucoup la valeur des économies réalisables. Roddickton est un des zone sites auxquels on a attribué une rentabilité marginale.

On estime à 125 mills/kWh le coût unitaire moyen de l'énergie produite par la mini-centrale de Roddickton, en supposant un taux d'escompte de 14 % et en étalant les coûts sur une durée de 30 années. En 1980, le coût du diesel utilisé à Roddickton était d'environ 54 mills/kWh. Si l'on suppose un taux d'augmentation annuel à long terme du coût du diesel de 10 %, on obtient un coût unitaire actualisé de 127 mills/kWh. Dans cette hypothèse, les rendements à long terme sont à peu près égaux aux coûts à long terme du projet.

A supposer que le taux d'escompte ne soit que de 12 % ou que les prix internationaux du pétrole soient pratiqués, le projet est rentable si on l'évalue sur toute la durée de la centrale. A ce taux, le seuil de rentabilité surviendrait au bout de 20 ans. Les résultats de l'analyse économique sont résumés dans l'Appendice C de ce rapport.

3. CONCLUSION

En incluant Roddickton, on estime que vingt-huit des quarante groupes diesel isolés de Terre-Neuve et du Labrador sont situés à des endroits qui pourraient être aménagés en petites centrales hydroélectriques. Le potentiel hydroélectrique total de ces sites est considérable et pourrait théoriquement satisfaire tous les besoins en énergie de la plupart des collectivités isolées actuellement desservies par de groupes diesel. De ces vingt-huit sites, treize ont peut-être le potentiel voulu pour remplacer jusqu'à 25 % de la production de groupes diesel en milieu isolé, mais onze d'entre eux n'auraient vraisemblablement qu'une rentabilité marginale. Ces treize emplacements représentent des économies annuelles possibles de 6,5 millions de litres de diesel.

Voici les avantages d'une mini-centrale hydroélectrique qui satisfait aux critères de la rentabilité: possibilité de remplacer du pétrole par une ressource renouvelable; stabilité des coûts de l'énergie à long terme; simplicité de l'exploitation et de l'entretien; effets négligeables sur l'environnement. Le principal problème est de réduire les coûts en capital de manière à améliorer la rentabilité de la centrale, puisqu'il est difficile de justifier un investissement dans un projet qui est au seuil de la rentabilité quand on ne sait pas comment évolueront les coûts du diesel. Il faut aussi tenir suffisamment compte de la rigueur du climat et de la très grande variabilité du débit du cours d'eau tout au long de l'année. L'accès aux lignes de transmission d'électricité et le grand déploiement de matériel de construction sont deux facteurs qui augmentent sensiblement les coûts d'un projet d'aménagement hydroélectrique en milieu isolé.

Le projet de Roddickton est un exemple de la conception et de la construction d'une mini-centrale hydroélectrique et donne une bonne idée des problèmes économiques et techniques que pose ce genre de travail. Le recours à des techniques simplifiées de construction et d'installation basées sur un type de turbine en particulier a produit, de façon générale, de bons résultats. Dans tous les projets semblables qui auront lieu dans l'avenir, il faudra accorder une attention particulière aux aspects suivants: prévoir un délai suffisant pour l'achat de l'équipement principal, voir à ce que les études faites sur le terrain en vue de confirmer les conditions du site et l'hydrologie aient lieu au moment opportun et en nombres suffisants, élaborer plus tôt les plans détaillés afin d'avoir suffisamment de temps pour obtenir les autorisations requises des organismes gouvernementaux, détailler les spécifications relatives à l'équipement et respecter rigoureusement les dates de livraison du matériel.

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PART I

ENGINEERING CONCEPTS, DESIGN AND ENVIRONMENTAL ASPECTS

INTRODUCTION

The Roddickton Project in northern Newfoundland was undertaken to "construct and operate a small-scale hydro development in a remote location without incurring prohibitive costs" and to "obtain the maximum construction input from the local community".

The single-unit plant utilizes approximately 47 m of gross head and a drainage area of some 23 km^2. The development involved construction of a timber crib dam 76 m long by 3.5 m high with a simple steel bell-mouth intake in the right side of the structure (looking upstream) and a 23 m^3/s capacity overflow weir, 0.7 m deep by 34 m long, cut into the dam on the left side to serve as the spillway. Because of the relatively low stream flow and high head, maximum turbine flow at 1.29 m^3/s is not high. Hence, a 800 mm nominal diameter polyethylene pipe was used for the 440 m pressure conduit.

The powerhouse building is a small, standard, pre-engineered industrial-type building, which houses a cross-flow turbine with rated speed of 451 r/min connected through a speed increaser to a 1200 r/min., 425 kW – 531.25 kV A synchronous generator.

The mini-hydro unit meshes with a pre-existing isolated system supplied by one diesel plant. The project includes a small supervisory control system that enables the diesel plant operator to operate the mini-hydro unit remotely. The development was completed January 1981 at capital cost of $1.23 million.

SITE DESCRIPTION

The project site is on Marble Brook, a small stream that flows into East Pond less than 2 km from Roddickton, a community on the east side of the Great Northern Peninsula in the Province of Newfoundland and Labrador (see Figure 7). The drainage area at East Pond is about 30 km^2 and the average stream flow is less than 1 m^3/s. The site itself is about 6 km upstream, where the stream exits into a small lake at an elevation of about 135 m. The average stream flow at this point was estimated to be 0.7 m^3/s. Upstream of this lake, the stream meanders through a

RODDICKTON MINI-HYDRO
PRE-CONSTRUCTION

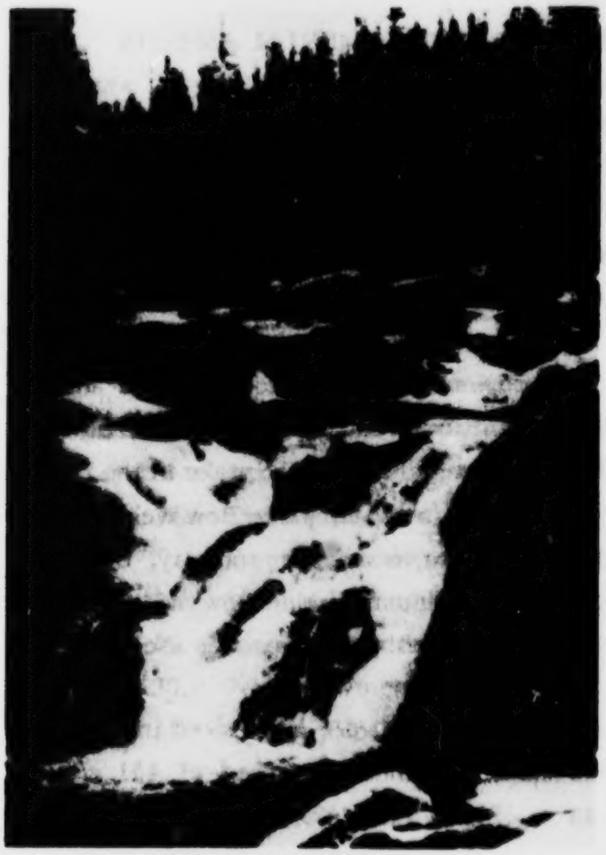


Figure 1

Typical View of Marble Brook
Prior to Construction.

Figure 2

View of Marble Broo
near Proposed Dam Si
Prior to Constructio

Figure 3

Area Immediately Downstream of Chosen Dam Location Prior to Construction.

Figure 4

Site Chosen for Powerhouse Location. Area around small island was backfilled and re-excavated.

Figure 5

Marble Brook Dam Site Location Looking Downstream.
Some clearing for centerline survey location evident.

Figure 6

Old Logging Dam Located Just Upstream of Mini-Hydro Dam Site.

relatively flat plateau and there are numerous shallow lakes, 10% or more of the watershed area being natural water surface. Downstream of the lake, the stream drops some 50 m quite steeply, via many rapids and low falls, within less than a kilometre.

The bed of the stream is strewn with boulders. Flood levels are not more than a metre above normal stream level and the lakes provide a high degree of regulation considering the small size of the stream. The lake, of about 300 000 m^2 immediately upstream of the site, forms a head pond.

PRINCIPAL CHARACTERISTICS OF DEVELOPMENT

Drainage area (km^2)	23
Average stream flow (m^3/s)	0.7
Gross head available (m)	46.9
Install turbine capacity (kW)	440
Annual energy (kWh)	1 500 000
System peak load (kW, 1980)	1 700
System energy demand (kWh, 1980-81)	6 000 000

EXISTING ELECTRICAL SYSTEM

The Roddickton Diesel Plant consisted of two 600 V, 312 kV·A diesels; one 2400 V, 700 kV·A diesel; and two 4160 V, 1250 kV·A diesels. It employed a local staff of five. The diesel plant is within 5 km of the project site and, in addition to Roddickton, there are two major load centres at the ends of some 43 km of distribution.

In addition to the domestic load, the distribution system services a sawmill load at the northern extremity, with a maximum motor size of 93.25 kW, and a fish plant load at the southern extremity, with the same maximum motor size.

The project site is approximately 1.6 km from a road and a 7200 V distribution line.

ENGINEERING CONCEPT

Engineering work progressed through the 1979-80 winter months to meet the project requirements generally as scheduled. Because of the small scale of the development, engineering design detail was handled exclusively in-house, using existing engineering staff on a part-time basis. The engineering concept was to provide drawings of sufficient detail to enable field staff (not a contractor) to execute the work. Field adjustments to the design were necessary but were not extensive.

All civil design drawings were essentially complete in the spring and turned over to the Construction Department. The Civil Design Section then provided upon request any additional work to support the field effort, as required. All major equipment was ordered in sufficient time by the applicable engineering design section.

POWER GENERATION EQUIPMENT PACKAGE SPECIFICATION

Following project release in early July 1979, the first engineering task was to produce a specification for Canadian suppliers or agents (by invited tender), which would be flexible enough to allow alternative turbine-generator packages with as many ancillary components as possible in a prefabricated design. In other words, precise specific detail was waived so that standard packages at economic cost could be accommodated.

Application of an induction generator was evaluated but because the mini-hydro unit was large (25%) in relation to the diesel system capacity, only a synchronous generator was considered in the tender specification.

A product research was initiated and was enhanced by a Stone & Webster Engineering Corporation Report[1] outlining small-scale hydro suppliers. This was somewhat academic since the tender was for Canadian supply and, although it allowed for fair assessment of all turbine types, the cross-flow type of turbine appeared to best suit the site conditions and cost considerations.

Tender call was made early in August 1979 and was closed on September 21. Only one bid was received and on October 17 notification of award was made to F.W.E. Stapenhorst of Pointe Claire, Quebec, exclusive North American agents for the Ossberger cross-flow turbine.

EQUIPMENT PACKAGE CONTENTS

The equipment package included the following:

- One Ossberger cross-flow turbine, designed for 42 m rated net head and 1.29 m^3/s flow, delivering 440 kW at rated head and flow.
- One oil-bath lubricated speed increaser, complete with oil circulating and cooling equipment.
- One 425 kW/531.25 kV•A, 1200 r/min., 60 cycle, three-phase, 4 wire, 600 V brushless, continuous-duty drip-proof synchronous generator, complete with automatic voltage regulator.
- One flywheel for increasing system WR^2.
- One plate steel draft tube and turbine inlet sections.
- One structural steel foundation frame for the turbine.
- One low-speed flexible coupling for 451 r/min., 1000 HP operation.
- One high-speed coupling, designed for 1200 r/min., 1000 HP operation.
- One Woodward speed governor size UG2, complete with hydraulic system, motor drives, etc.
- One set of gate-operating servomotors.
- One 30 inch – 150 psi, automated butterfly valve complete with one loose flange.
- One set of necessary foundation bolts; piping and electrical wiring devices for interconnecting the governor, pump, controls and servomotors; servomotor linkages, restoring cables, spare packings, bearings, gears.
- One electrical control board with necessary basic electrical controls required for monitoring the electrical output and protection of the generating unit, but excluding generator main breakers, high-tension and heavy cables and any equipment to be installed in places other than the powerhouse.

Although the package was not all-inclusive, it was nevertheless satisfactory. Significant and positive alterations were made, afterward, to the net head and rated flow figures before the final package design was completed. Problems experienced with the package were execution on a very tight schedule and difficulty in co-ordinating specific protection and control requirements such as relays and instrumentation in the electrical control board.

TURBINE DETAILS

The concepts of the Ossberger cross-flow turbine is not new. The turbine is of the impulse type and is named 'cross-flow' because the water crosses the runner twice. It was invented at the beginning of the century by A.G.M. Michell, an Australian engineer and further developed by an Hungarian engineer, Professor Banki, who was responsible for its popularity. Shortly after World War I the patents were obtained by the Ossberger Turbinen Fabrik of Weissenburg, Germany. Since then, this company has designed and manufactured over 7000 of the turbines.

The water is directed through a rectangular jet to a cylindrical runner, and the outward flow cleans the blades of any debris, ice or other foreign matter that may have entered the turbine (see Figure 8). The cross-flow is particularly adaptable to wide variations in head and flow. Its efficiency curve is essentially flat, making it suitable for our run-of-the-river operation. This high efficiency, even down to 15% of rated flow, is achieved by the guide vane design (see Figure 9).

The guide vane is hydraulically precision balanced. It is split into two sections, one covering one-third and the other two-thirds of the runner. Up to one-third of the flow, only the small gate is open. After that, the large gate opens up and at medium flow, the large section is open and the small section closed. At maximum flow both sections are open.

The multibladed runner is made of cold drawn steel and was dynamically precision balanced prior to its assembly into the housing. Standard roller bearings were used for the runner. The guide vane bearings are of white metal. The shaft seal packing is also standard. Although units could have been supplied with an automatic vacuum breaker valve in the turbine housing to regulate the tail water level, the unit setting did not require it.

The turbine is suplied with an intake transition piece between the pressure conduit and the turbine. This is round at the end that fits the pressure pipe and rectangular at the other end to be bolted to the turbine housing. The draft tube is rectangular to fit the turbine housing to which it is bolted and it has a round outlet. It is straight rather than elbow-shaped.

The turbine is generally supplied completely assembled, mounted to a frame which is bolted to the floor, and the draft tube and the transition piece are screwed to the assembly at installation. There were no parts imbedded in the concrete other than anchor bolts, which were grouted in later. Only a strong floor with a hole in it was required. The equipment package contract provided for erection supervision and testing which was expected to take no more than two weeks.

CIVIL DESIGN

The basic design concept of the Roddickton Mini-Hydro Development was 'design as you build' in the field. However, a preliminary design was done to establish the stability of structures and to determine the quantity of materials required. As construction progressed, necessary changes were made to suit the site conditions. However, these changes were not extensive.

1. DAM

A rock-filled timber crib dam 5 m wide at the base and of 3.5 m average height was designed for this project. Various alternative types of dams and locations were considered.

Location

Two possible locations were considered for the dam – one at the outlet of a lake at the site of an old logging dam, and the other about 80 m below the mouth of the lake in a naturally formed neck in the streambed topography. Location of the new dam at the outlet of the lake would have minimized the size of the dam. However, additional work and cost would have been involved in removing the old logging dam and in additional lengths of pressure conduit and access road. Furthermore, extensive work in the lake would have been required to construct an intake with a suitable head pond. The location about 80 m downstream from the lake was chosen because it allowed creation of a suitable head pond and because an intake could be incorporated into the dam with minimum work.

Type

The following alternative types of dams were considered:

Concrete Dam at Selected Site. Concrete dams are preferred for durability and ability to accommodate heavy flood overflows. They are also virtually impermeable. However, they are expensive to construct, especially in this case where facilities necessary for site mixing with the required quality control would not have been possible for the quantities involved. Therefore, this proposal was deemed unfeasible.

Earth-Fill Dam. Because of the remote site, the cost of transportation of the materials and heavy equipment necessary for construction of this type of dam was high, and it was rejected.

A-Frame Timber Dam. Extensive rock anchors are required for this type of dam, which are very expensive. Also, its construction and maintenance are labour-intensive. This proposal was not acceptable.

Rock-Filled Timber Crib Dam. This type of structure (see Figure 10) was selected for the project because (a) it is simple to construct; (b) though the construction is labour-intensive, the skills required were readily available; (c) this type of dam can be overtopped without damage, if this possibility is taken into account; (d) availability of construction material required was not a problem; and (e) incorporation of intake structure is possible, allowing comparatively less expensive installation and access to trash racks.

Design Details

Although timber crib dams are common in Newfoundland, only a little detailed information on their design and construction was available, despite inquiries to available sources.[2,3]

There were no firmly established criteria for dam stability. However, based upon experience, failure of these dam types seemed more frequently due to sliding than to overturning. It was suggested that for stability against sliding, the unit vertical weight of the structure should be between 2.5 and 4 times the horizontal water pressure.

Ice thrust design was approximated. No historical data were available regarding the thickness of the ice sheet on this pond. However, since the thrust is a function of the rate of change of temperature and of the side slopes of the pond, the design thrust due to ice was left to the discretion of the engineer. A sheet of ice 1.0 m thick was assumed, as suggested in the feasibility study, and therefore a thrust of 24.61 kip/m was used in the design. Though the factor of safety against overturning was 1.5, rock anchors were used as an additional safeguard against horizontal shear.

To determine the unit weight of the crib dam, the following proportions were used: void 20% of unit volume, timber 20% and rock 60%. On this basis, the average unit weight of the dam used was 1285 kg/m^3.

Minimum excavation was anticipated from visual inspection of the site. The centreline of the stream is 132.1 m high and toward the end of the dam the elevation is 133.2 m. The design provided for four steps in the bedrock with a minimum excavation of 0.4 m to a maximum of 0.8 m. The top of the dam is 135.4 m high.

The upstream face of the dam was covered with one layer of 50 x 150 mm timber under a top layer of 25 x 150 mm timber with joints staggered and a 0.25 mm polyethylene vapour barrier between the layers. Metal flashing was used to protect the edges of the timber planks. Impervious fill was used on the upstream face to minimize seepage.

Intake and Spillway

These items are all incorporated into the timber crib dam. The intake consists of a conventional bell-mouth structure and a trash rack with a 20 x 20 mm mesh to suit turbine requirements. Provision was also made in the intake area for stoplogs (see Figure 11). The intake is in the right side of the dam, looking upstream, and a 23 m^3/s capacity overflow weir, 0.7 m deep by 34 m long, cut into the dam on the left side, serves as the spillway.

2. PRESSURE CONDUIT

For a mini-hydro development, the terrain may not lend itself to large head concentrations and therefore the pressure conduit must be of significant length. Moreover, the severe climatic conditions imposed by northern locations make protection against freezing a prime concern. As a result, the cost of the pressure conduit is a large portion of the total capital cost and it is therefore critically important that they be minimized by careful selection of material and installation practices.

The engineering evaluation recommended the use of polyethylene pipe after consideration of steel, wood, fibreglass, ductile iron and high-pressure ductile pipe. This recommendation was reviewed and accepted. A preliminary field survey was conducted to determine alignment and to minimize the excavation. The pipe is designed for both static and surge pressure. A computer program by the supplier determined the pressure gradient at the turbine end for various closure times. An 800 mm nominal diameter pipe was selected that had ratings of 5.62 kg/cm^2 (80 psi), 4.22 kg/cm^2 (60 psi) and 3.16 kg/cm^2 (45 psi), to cover a distance of 439 m.

The pipe was buried under a minimum cover of 500 mm. Five concrete anchor blocks were required, located at the powerhouse, on steep slopes and at bends. To prevent ice from forming in the pipe during any prolonged winter shutdowns, there is a manually operated butterfly valve and a vacuum breaker valve at the intake structure to enable draining. A study determined that still water would freeze within 363 hours with the 500 mm cover, within 48 hours with no cover and within 640 hours with a 1370 mm cover.

3. POWERHOUSE

The powerhouse building was pre-engineered with dimensions of 8535 mm x 6090 mm. A wooden building of similar cost was considered but because of custom design and fire hazard the pre-engineered type was preferred. There are no interior partitions or domestic water facilities (see Figure 12). The optimum location was selected after consideration was given to head gain, increased pipe length and site conditions.

The building configuration was dictated mainly by the type and size of the turbine. The reinforced concrete substructure was anchored to a rock foundation at the site. A small platform for the turbine was provided as recommended by the manufacturer and a tailrace channel 2.5 m high x 4.0 m wide was excavated to Marble Brook, the natural watercourse, some 30 m away.

ELECTRICAL-MECHANICAL

As mentioned above, the intake has a manually operated butterfly valve to drain the pressure conduit in the event of a prolonged winter shutdown. The pressure conduit incorporates a vacuum breaker valve, which will be heat traced. The intake area includes a pressure transmitter for water level measurement. These items necessitated AC power to the intake, which was stepped down from 7200 V primary construction. This primary tap as well as a short tap from the powerhouse to a radio repeater site were included with the 1.6 km of 12.5 kV 3ϕ new construction to the site and the 4 km upgrading of existing distribution in a tender package handled by the Power Distribution District. This work was completed by August 1980.

The mini-hydro plant is operated from the Roddickton Diesel Plant, where the operator adjusts load based upon headwater indication and controls the reactive power output of the plant. These functions are available through a mini-supervisory system, which cuts operating costs. Synchronization is manual only at the hydro plant.

Direct current requirements are generated from a 48 V battery and charger of 100 A-h rating. Interconnection to the system is through single-phase 7200/600 V transformation and the station service AC power requirements are fed from a single-phase 7200/120/240 V supply.

Other electrical-mechanical design items included equipment layout (see Figure 13); powerhouse heating, lighting, wiring and grounding; 600 V power circuit breaker; power cables and their layout; and co-ordination to the system of the protection and control requirements of the unit.

ENVIRONMENTAL ASPECTS

The environmental aspects of the Roddickton Project were less straightforward than the Newfoundland and Labrador Hydro's Environmental Services Department first anticipated. Small-scale hydro projects have all of the elements of a large project. This site had to contend with a municipal water supply downstream and with possible salmon stream disruption.

Small projects are not subject to extended formal review processes by government agencies. The federal government, which funded the project, made agreement to have the provincial Department of Consumer Affairs and Environment review the project under Water Resources, Section 29, of the Environmental Act. The Act also provided for municipal water supply protection. The federal Department of Fisheries and Oceans was consulted for approval under the Fisheries Act. A study conducted by Labrador Hydro at the request of Fisheries showed that salmon migration and spawning would not be affected by the site chosen and Fisheries forwarded their approval of the location to the federal Department of Energy, Mines and Resources and to provincial Environment. Preliminary agreement was then made with Environment for general protection of the water supply area.

By project design, engineering details would be available just before the start of construction. The general outline showed no cause for concern. Final approvals were obtained from Environment and from Fisheries for culverts, transmission lines, plant dam and spillway construction, each of which depended on engineering data.

Approximately one month before construction was to commence, engineering drawings were released, revealing that the timber crib dam was to be treated with a preservative. Normally this is of no great concern, even for a municipal water supply. However, the dam site was larger than anticipated and, in consideration of possible concentrated amounts of water in contact with the dam during low runoff operation, engineers decided to use untreated timber rather than incur delays and further costs in studying and demonstrating alternatives. Therefore, western hemlock timber with a life expectancy of 18 to 20 years will be used.

Annual plant operation plans were difficult to demonstrate because of the correlated hydrological data. Although the mean annual discharge in the brook was not expected to change, Fisheries required a water release facility to maintain a minimum flow of 200 l/s from the powerhouse to the downstream brook. Further interdepartment co-ordination is continuing to relate efficient plant operation with acceptable downstream flow requirements.

Initial design previsioned cofferdamming to divert water to another stream in order to work on the dry streambed. Federal Fisheries vetoed this because of the downstream fish population. More extensive hydrological data on the brook might have shown that cofferdamming was possible. Without this data, water diversion was redesigned so as to cofferdam one side of the work area and then the other.

It is company policy to have site environmental monitors for project construction. The size and budget of this plant did not permit a full-time site representative. Site visits were undertaken by staff assigned to other projects.

By definition these projects are located near load demand. The Roddickton Town Council were justifiably active in participation, providing another government level with which to communicate. They requested early information on the project and a review of plans such as the contingency plan for an alternative water supply, should the project affect the present system.

CONCLUSION

The mini-hydro project has demonstrated generally good experience in simplified construction and installation based upon the facility of a particular turbine type. For any future similar projects, further attention and consideration should be given to lead time for major equipment package purchases; to the amount and timing of field surveys to confirm site conditions and hydrology; and to earlier completion of design details to allow sufficient time to obtain approval from environmental agencies.

PRELIMINARY AND CONCEPTUAL DRAWINGS

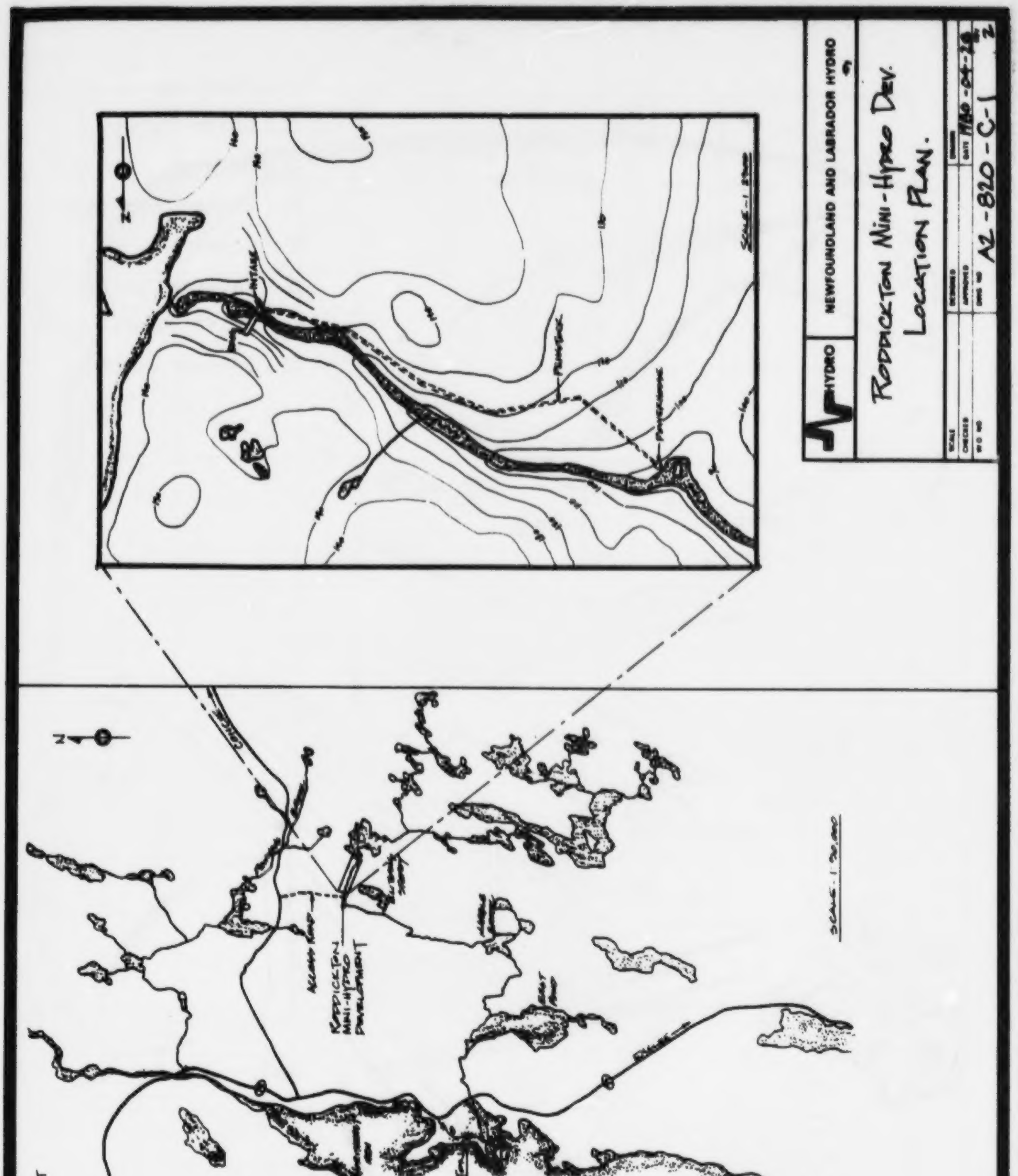
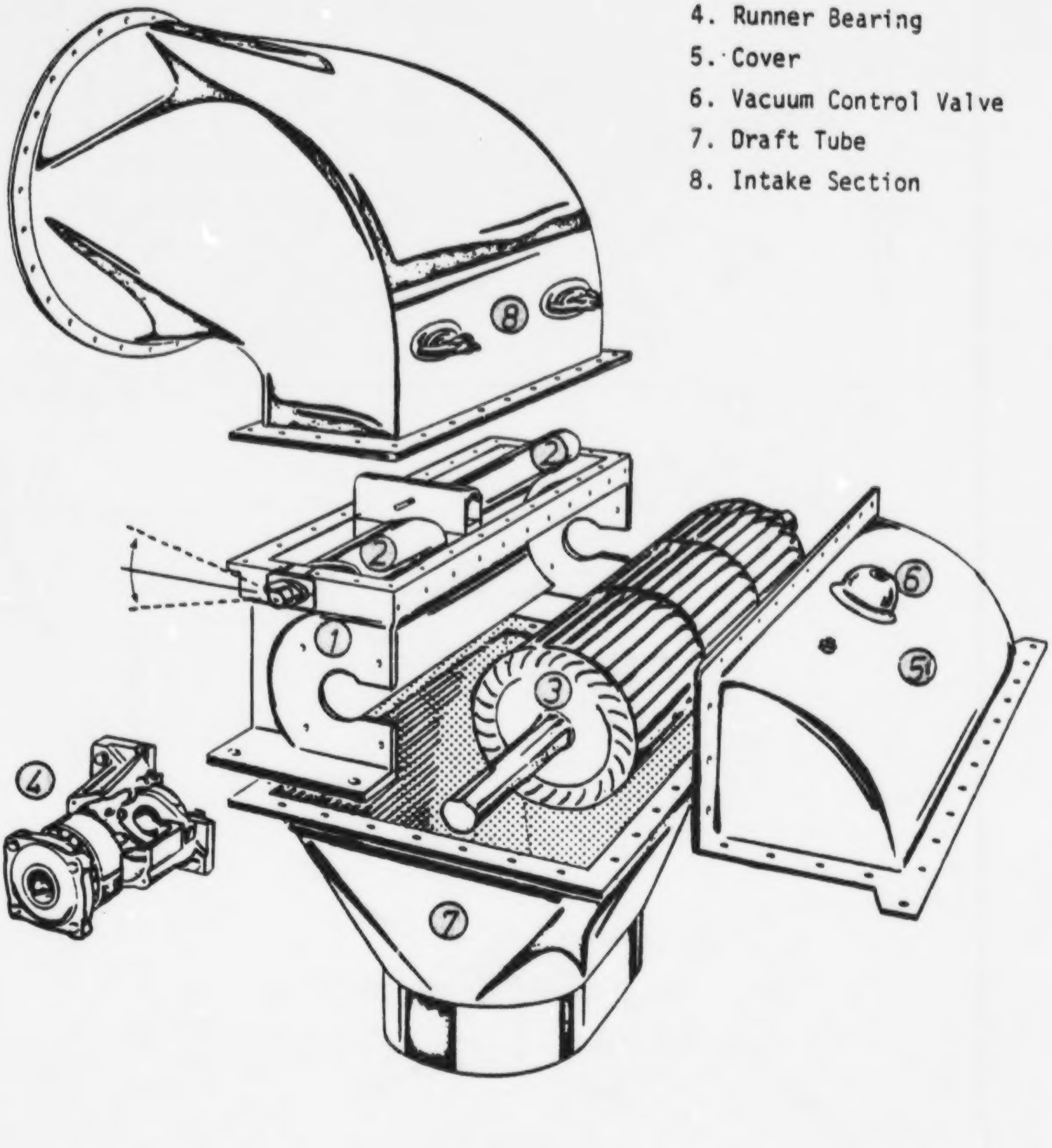

HYDRO
NEWFOUNDLAND AND LABRADOR HYDRO
RODDICKTON MINI-HYDRO DEV.
LOCATION PLAN.
1980-04-28
A2-820-C-1
INTAKE
PENSTOCK
POWERHOUSE
SCALE 1:5000
RODDICKTON MINI-HYDRO DEVELOPMENT
RODDICKTON
SCALE 1:50,000

Figure 7



1. Housing
2. Guide Vanes
3. Runner
4. Runner Bearing
5. Cover
6. Vacuum Control Valve
7. Draft Tube
8. Intake Section

Exploded View of Typical Ossberger Turbine Assembly

Figure 8

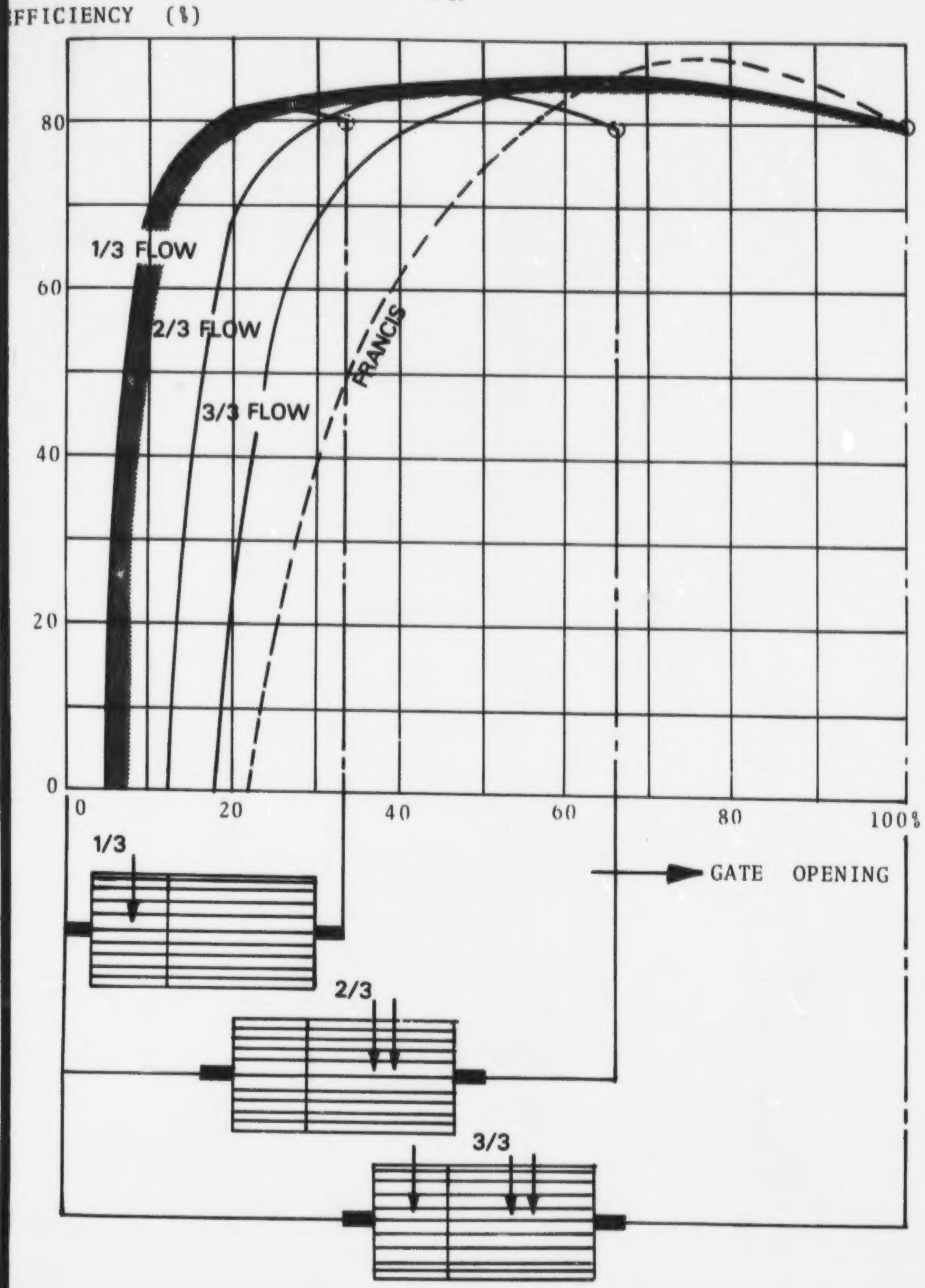

FFICIENCY (%)
80
60
40
20
0
1/3 FLOW
2/3 FLOW
3/3 FLOW
FRANCIS
0
20
40
60
80
100%
GATE OPENING
1/3
2/3
3/3

Figure 9

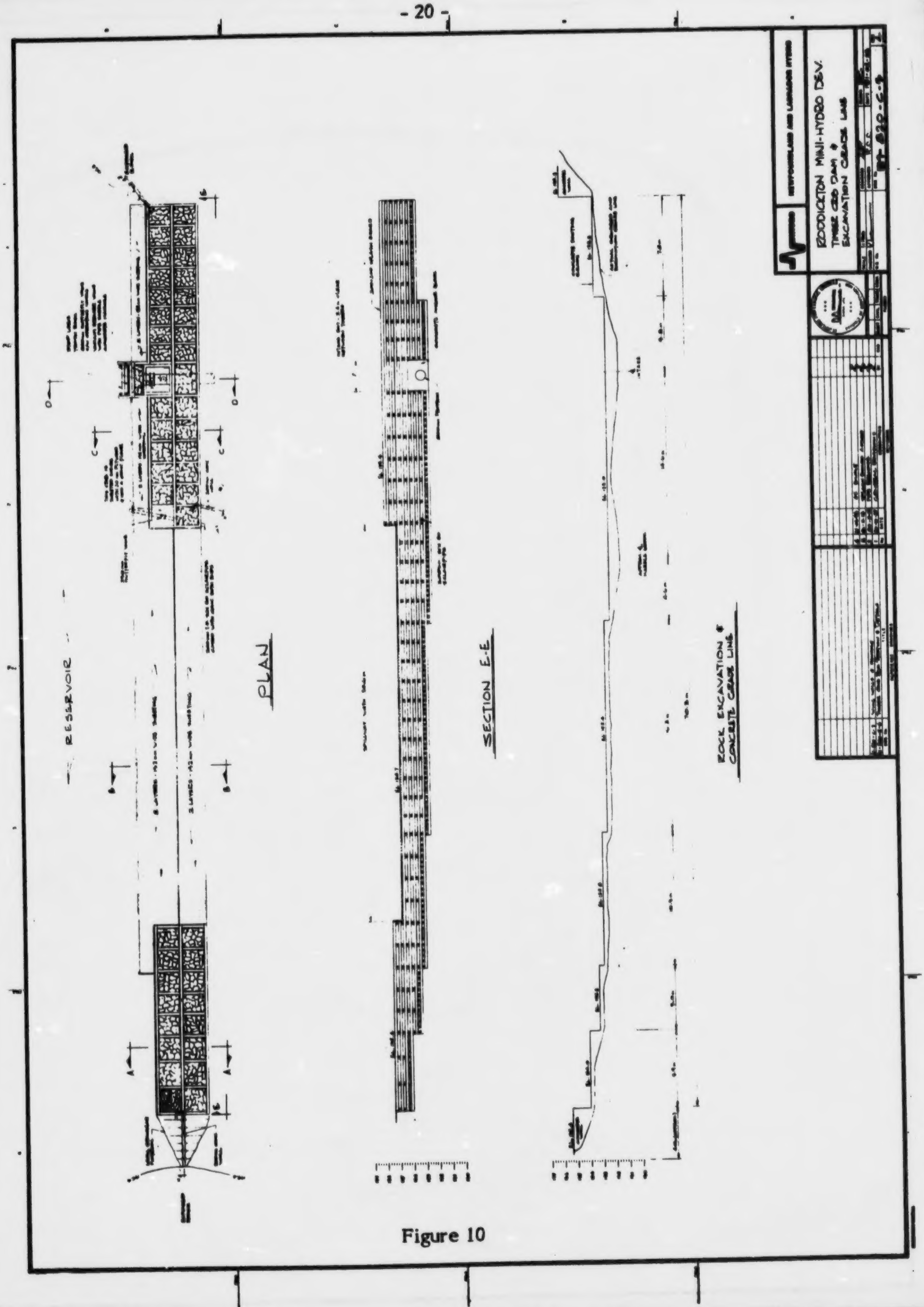
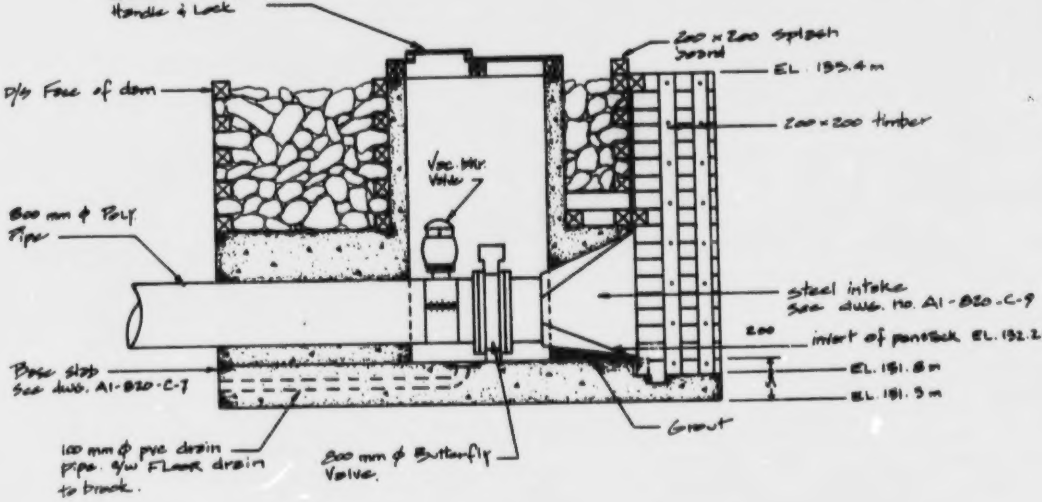
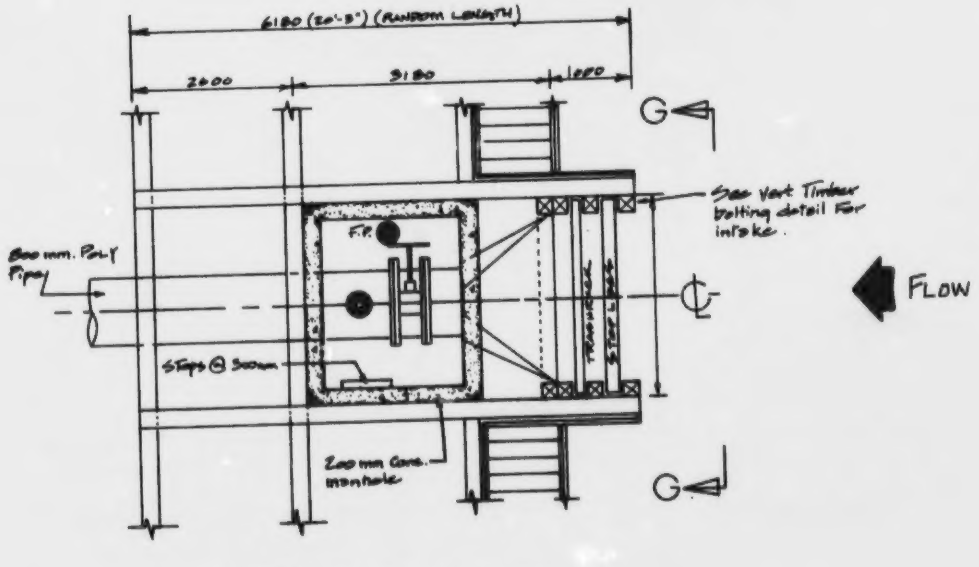

NEWFOUNDLAND AND LABRADOR HYDRO
BODDICKTON MINI-HYDRO DEV.
THREE CRIB DAM &
EXCAVATION GRADE LINE
RESERVOIR
PLAN
SECTION E-E
ROCK EXCAVATION &
CONCRETE GRADE LINE
A
B
C
D
E

Figure 10

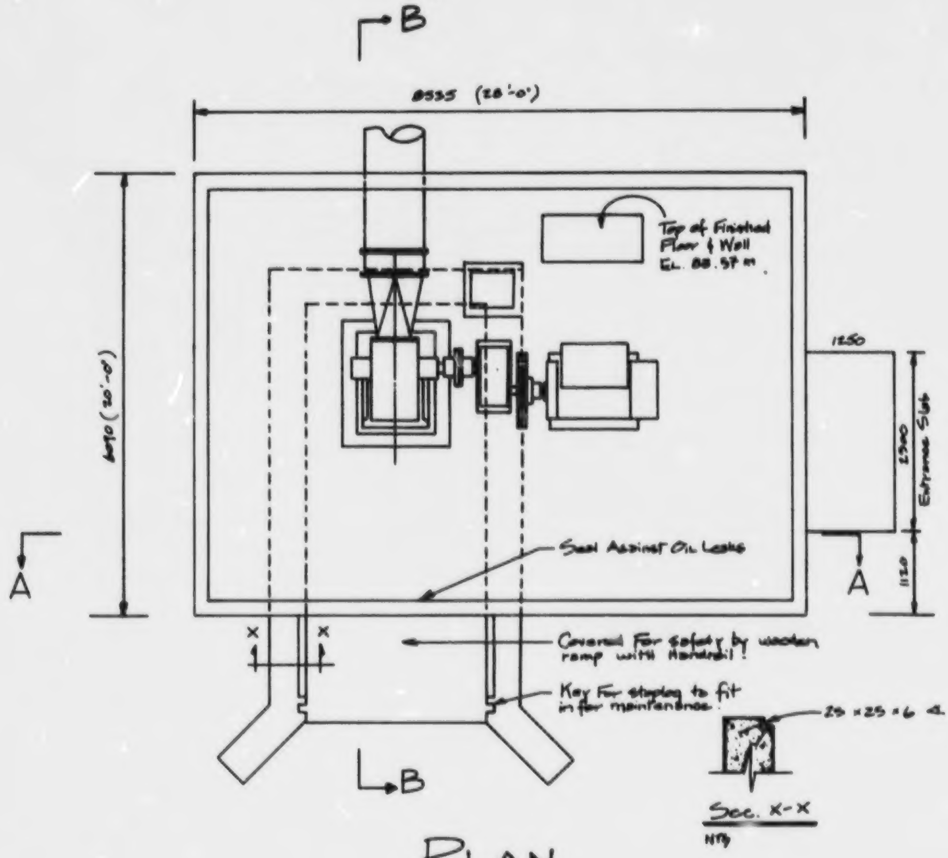

Wooden cover c/w Handle & Lock
200 × 200 Splash board
EL. 133.4 m
D/S Face of dam
200 × 200 timber
Vac. Rlr. Valve
800 mm ⌀ Poly Pipe
steel intake See dwg. No. A1-B20-C-9
200
invert of penstock EL. 132.2m
Base slab See dwg. A1-B20-C-7
EL. 131.8 m
EL. 131.3 m
Grout
100 mm ⌀ pvc drain pipe c/w Floor drain to brook.
800 mm ⌀ Butterfly Valve.

SECTION D.D.
1:50

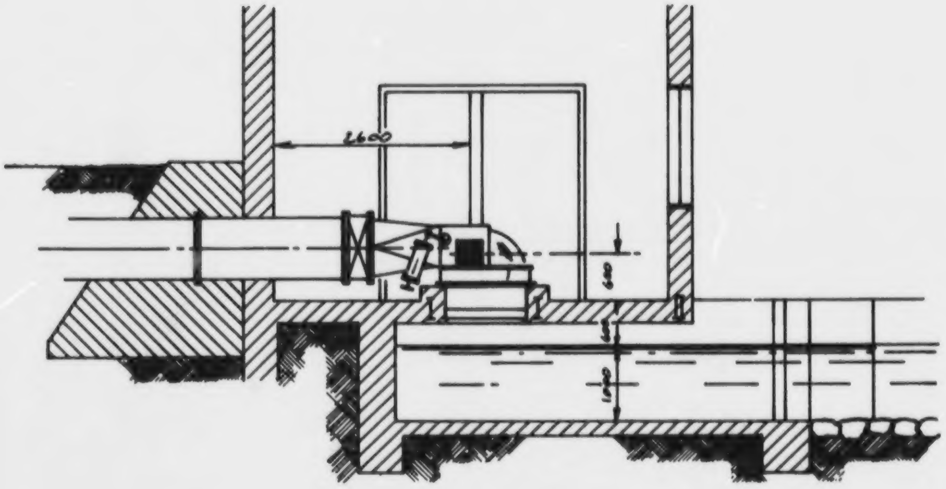

6180 (20'-3") (RANDOM LENGTH)
2600
3180
1000
G
G
See Vert Timber bolting detail For intake.
800 mm. Poly Pipe
F.P.
TRASHRACK
STOP LOGS
℄
FLOW
Steps @ 300mm
200 mm Conc. manhole

PLAN OF INTAKE
1:50

Figure 11


B
8535 (28'-0")
6090 (20'-0")
Top of Finished Floor & Wall EL. 88.57 m
1250
2300
Entrance Slab
1120
Seal Against Oil Leaks
A
A
X
X
Covered For safety by wooden ramp with Handrail!
Key For stoplog to fit in for maintenance.
25 × 25 × 6 ∠
B
Sec. X-X
NTS

PLAN
1:50


2600
600
1000

CROSS SECTION

Figure 12

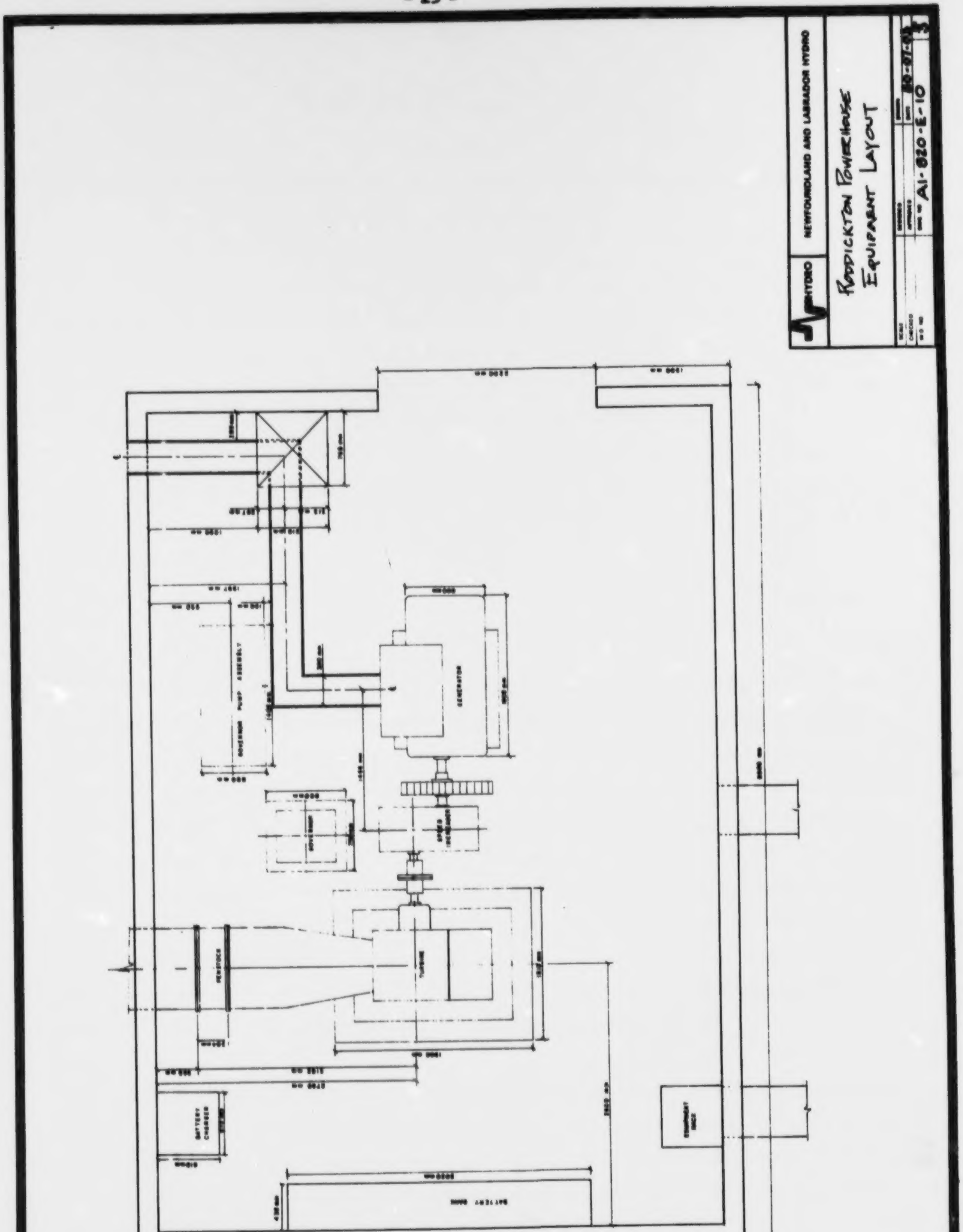

HYDRO
NEWFOUNDLAND AND LABRADOR HYDRO
RODDICKTON POWERHOUSE
EQUIPMENT LAYOUT
A1-820-E-10
GOVERNOR PUMP ASSEMBLY
GENERATOR
GOVERNOR
SPEED INCREASER
PENSTOCK
TURBINE
BATTERY CHARGER
BATTERY BANK

Figure 13

PART II

CONSTRUCTION METHODOLOGY, OPERATIONAL CONSIDERATIONS, PROJECT DATA AND COSTS

The Roddickton Project was begun in the fall of 1979 with the construction of the access road. However, the main construction was scheduled for 1980 to meet the commercial on-power date of October 1980. Coincident with the initiation of the construction program, a budget, cost and forecast system was implemented and manpower and resource schedules were produced.

The civil portion of this project consisted of four major components: access road, dam and intake, penstock and powerhouse. In addition, the mechanical-electrical components consisted of the plant equipment package, and the electrical and telecontrol equipment.

ROAD

Prior to undertaking construction of the access road, a meeting was arranged between the Town Manager for the town of Roddickton and the Project Engineer to outline the scope of the project, its aims and the scheduling of the work. This was done to gain local support for the project, to evaluate the resources available in the Roddickton area and to prepare the town officials with answers to questions that would certainly arise when construction commenced. Because unemployment in the area was high when the project was started, plans regarding manpower requirements and schedules were explained. As a result of this meeting, office space was rented in the Town Hall and the names of equipment owners local to the Roddickton area were obtained. These owners were later contacted or visited, to ascertain the types and capacity of equipment, availability, rental rates and local labour rates.

The local station of the Department of Forestry and Agriculture was visited to obtain permission to cut and clear for the development. In addition to securing the necessary permits, a copy of the Forestry Specifications used in building local 'resource roads' was obtained and discussions on local road construction provided further useful information.

Through contacts in Roddickton, an experienced foreman with road-building experience and an office clerk were hired. The foreman was given authority

ACCESS ROAD CONSTRUCTION

Figure 14

Rock Drilling for Access Road Construction.

Figure 15

Construction of Access Road through Side Hill Rock Cut.

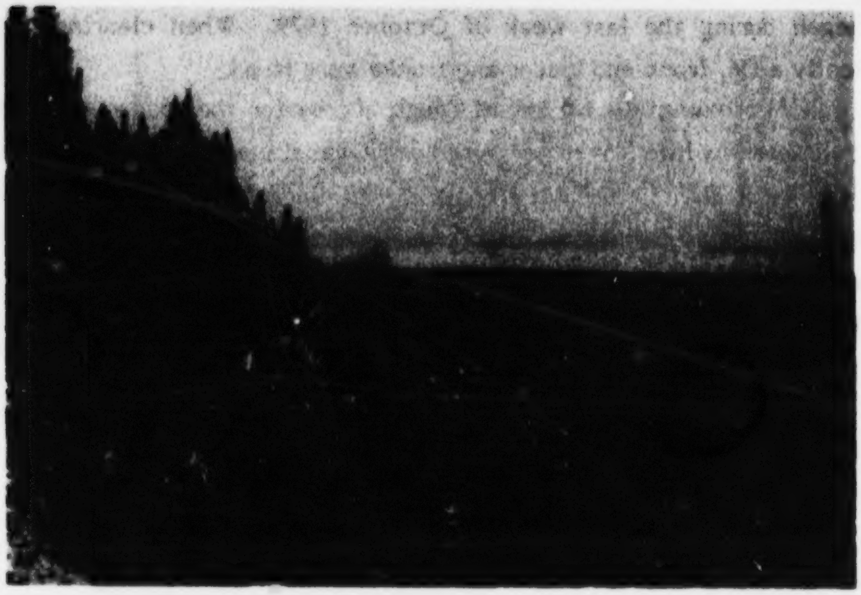


Figure 16

Access Road along Penstock Route.
Steep side hill to Marble Brook at right.

Figure 17

Completed Section of Access Road. Note timber salvaged for sale to local mill.

to hire a local labour force of five woodsmen and actual on-site work on the access road began during the last week of October 1979. When clearing had advanced sufficiently a D6, front-end loader and trucks were hired.

Approximately 1.5 km of rough access for the roadway to Marble Brook were completed by late November, when work was discontinued for the winter. When work resumed in mid-June 1980, a complete grading of the existing road was in order and the final section to the powerhouse and dam (0.5 km) was started. The mid-June date was determined by the spring breakup, which is later in the Roddickton area than in most parts of the island, and by a request from federal Fisheries to defer work in Marble Brook until June 1 to avoid the spawning season.

The first major problem encountered was at the Marble Brook crossing. The flow in the brook was quite high and, to stay on schedule, the culverts had to be placed and backfilled in the water. Field conditions made this unavoidable and diversion of the brook was impractical. The culverts had to be restrained until backfill was almost completed and rip-rapped. Local machinery was used to grub the right-of-way but it soon became evident that this machinery could not complete the job within schedule, as the largest equipment in the area was a D6. Also, the gradient from the powerhouse to the dam was quite steep and rough for the first 150 m and was on a sharp side hill over the next 200 m of the approximate 430 m length. Subsequently a heavier machine, a D8 with ripper, was brought in and completed the job expeditiously.

Some blasting was undertaken at several points to decrease the road grade to less than 10° where possible. Grade realignment was also undertaken by local machinery (one airtrac and 600 CFM compressor) and frequent breakdowns again slowed progress. The road was essentially completed by mid-July. The use of local equipment, which was of older vintage and susceptible to more breakdowns, was a compromise. The local equipment was available generally at lower rates, required little mobilization notice or expense and represented local community input. However, reliability was lower. These factors require special consideration when selecting equipment services that are critical to the schedule.

DAM

Excavation to the rock grade was the first step in constructing the dam. This operation started in late July and the actual location of the dam and intake was specified following the removal of overburden. A site was chosen that gave minimum

DAM CONSTRUCTION

Figure 18

Grubbed Dam Site. Uneven rock outcrops in foreground.

Figure 19

Clearing of Rock to Receive Leveling Concrete.
Much of this required hand labour.

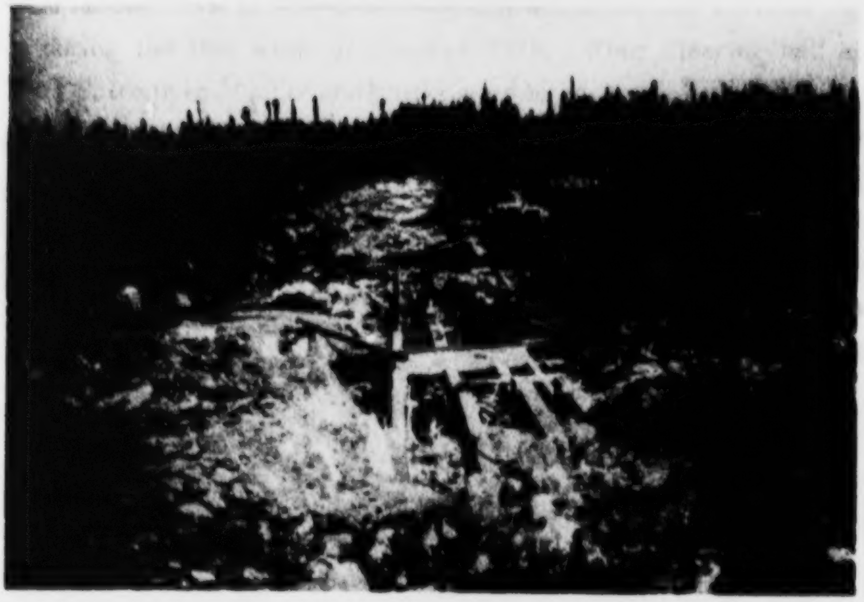


Figure 20

Constructing Concrete Foundations to Receive Timber Cribbing.

Figure 21

Early Stages of Crib Construction Looking from South Shoulder of Dam.

Figure 22

Dam in Intermediate Stage of Construction

Figure 23

Dam De-Watered to Allow Completion of Upstream Sheeting.
Note pipe for water compensation.

Figure 24

Completed Dam Watered Up. Intake structure with frame to allow lifting of trash racks in foreground. Spillway section at right center.

width consistent with good shoulders and bottom conditions. The concrete footings for the dam were constructed on the original rock, except where extreme rock variations necessitated blasting. The blasting was kept to a minimum and small shots were employed. Even so, the irregular bottom made this levelling time-consuming, since the only available equipment suited for this work were the 600 CFM airtrac and compressor and a 150 CFM jackhammer and compressor, which were prone to frequent problems.

A continuous transverse concrete footing, 457 mm wide and at various elevations at multiples of 200 mm (to correspond to timber thicknesses), was built under each transverse bottom timber. Horizontal spacing of these timbers was indicated by the dam cross-section drawings. A low upstream dyke approximately 100 m long also was required to enclose a low spot on the northwest side of the reservoir. It was built simply by filling the low area with local material. This was accomplished in a week with the D8 tractor.

The dam timbers (200 x 200 mm) were moved to site from dockside at Roddickton by local trucks and loading equipment. The timbers were placed as soon as the concrete footings and rock dowels were in place. The dowels were embedded for 1 m and bolted through the two bottom layers of timber. Galvanized drift pins of 50.8 cm and 30.48 cm were used at each timber intersection. Galvanized machine bolts fastened the vertical stiffening timbers to the cribs. Portable generators and heavy-duty electric drills were used.

Placing the timbers and filling the crib with rock proceeded fairly slowly because initially the workers were inexperienced and also because machinery frequently was unavailable to move materials at site. The continuous heavy runoff from the dam also slowed construction by affecting dewatering in the dam area. The unusually wet summer necessitated constant cofferdamming as high runoff persisted. This had a detrimental effect on the schedule since little or no cofferdamming during July and August had been anticipated. The limited area of construction involved substantial moving of smaller cofferdams since complete cofferdamming was not permitted by the federal Department of Fisheries and Oceans, as a measure against possible danger to fish stocks. The dam sheeting and intake work were undertaken following the placement of the timber. Sheeting consisted of a layer of 52 mm plank covered with an outside layer of 25 mm plank separated by a film of plastic 0.2 mm thick.

The dam was substantially complete by the end of October 1980. Other items such as dam retaining walls, intake covers, manhole concrete, and the water release facility required by Fisheries were completed concurrently as the timber placement permitted.

More preliminary investigation, such as test pits, would have been useful for both the design and construction phase and to improve the accuracy of quantity estimates. However, this must be balanced against the cost of obtaining such information.

PENSTOCK

Following the clearing, grubbing and alignment of the route, excavation started in July at the dam site end where earth excavation was required. The excavation material consisted of approximately 60% earth and 40% rock. Maximum cut was about 4 m. As excavation continued, sand for the pipe bed was trucked to the site and stockpiled.

When substantial excavation was completed the sand bedding was installed. Approximately 300 mm of sand bedding was placed on the bottom of the trench and graded. The excavation and bedding were completed before the jointing machinery arrived. The main equipment used for this jointing and placing were the jointing machine, a 3Ø, 10 kW, 220 V AC generator, a boom truck and trailer for delivering pipe to the jointing machine, a .57 m^3 excavator to lift the penstock into the trench excavation, a D8 to pull the joined pipe along the trench, and compacting equipment to compact the sand bedding. One small section was left unexcavated at the dam site as a plug to protect against possible water flow should the cofferdam fail.

The pipe was joined by butt fusion in which the ends of the polyethylene pipe are heated and held together under pressure. This fuses the joint, which is then allowed to cool, and the pipe becomes continuous. Joining the pipe required eight days and was completed by the first week of October. Mechanical joints were provided at three locations and at both ends of the penstock. At the end of the eight days, all the pipe was placed and bolted except for the last section, which was delayed because the upstream valve had not arrived, thus requiring that the small unexcavated plug be left in place.

While the pipe was being placed, the first anchor block was poured, fixing the pipe position at the powerhouse. At the anchors, the polyethylene pipe was strapped in a thin rubber gasket over which were placed three steel straps to improve bonding between the concrete and the penstock.

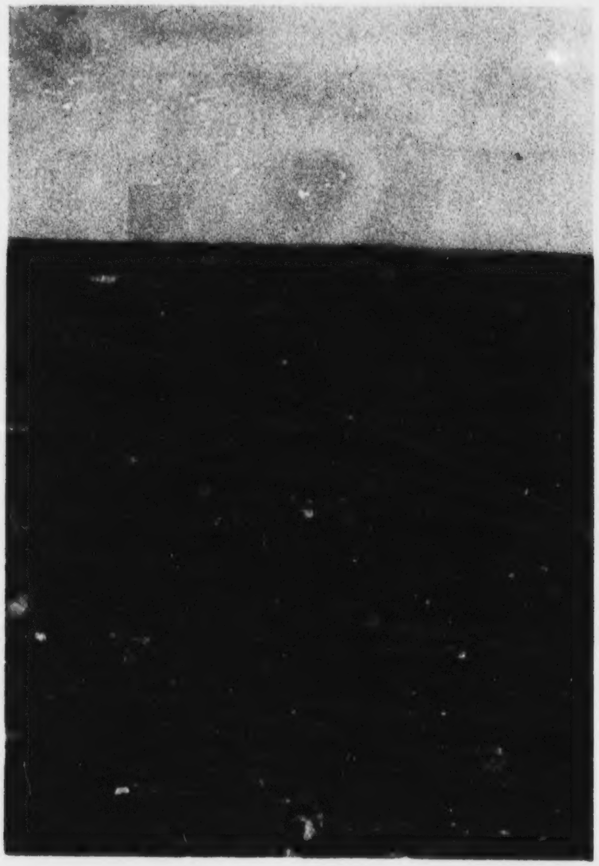


Figure 25

Excavation for Penstock Trench.
Material encoutered was approximately
60% earth, 40% rock.

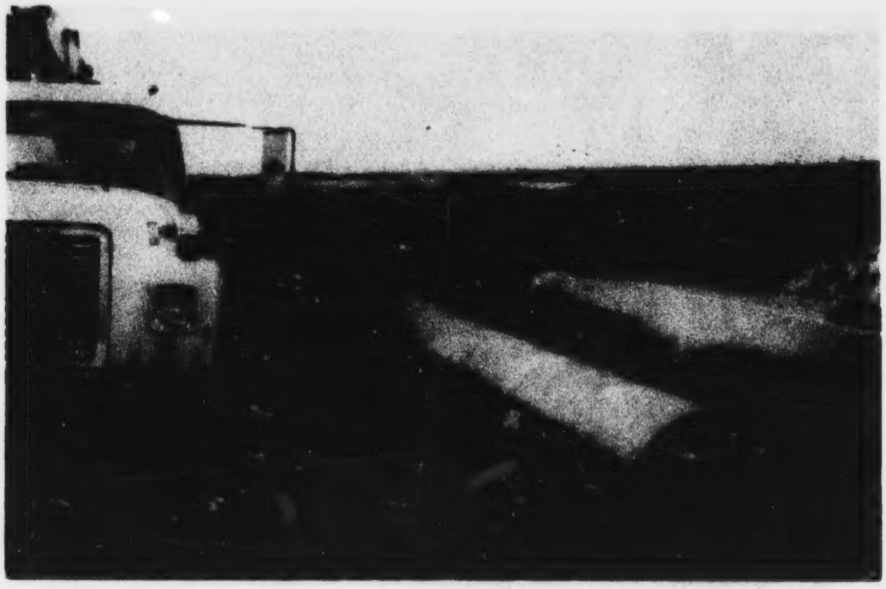


Figure 26

Polyethylene Pipe Awaiting
Jointing. Approximately 440 m were
joined in eight (8) days.

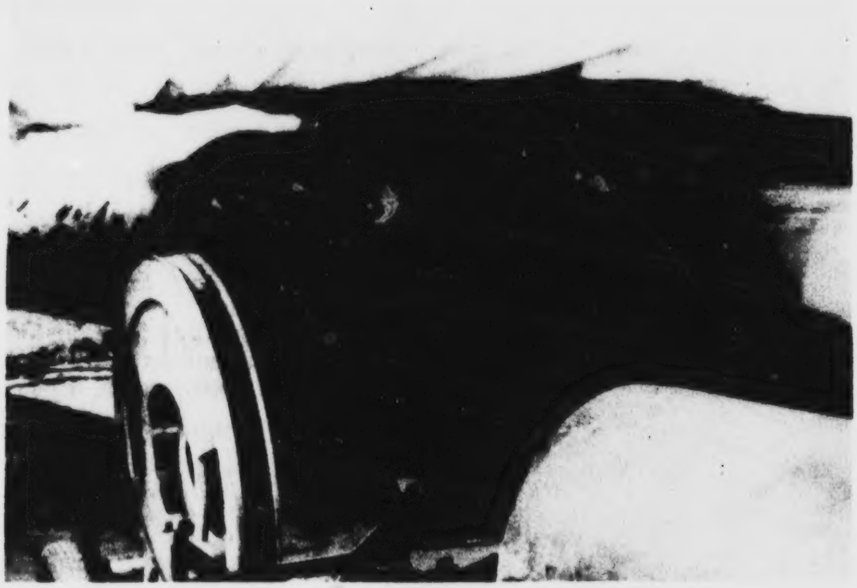


Figure 27

Closeup of Jointing Machine. Heated ends of pipe are held together under pressure until fused.

Figure 28

800 mm Penstock in Place in Trench Ready for Backfilling.

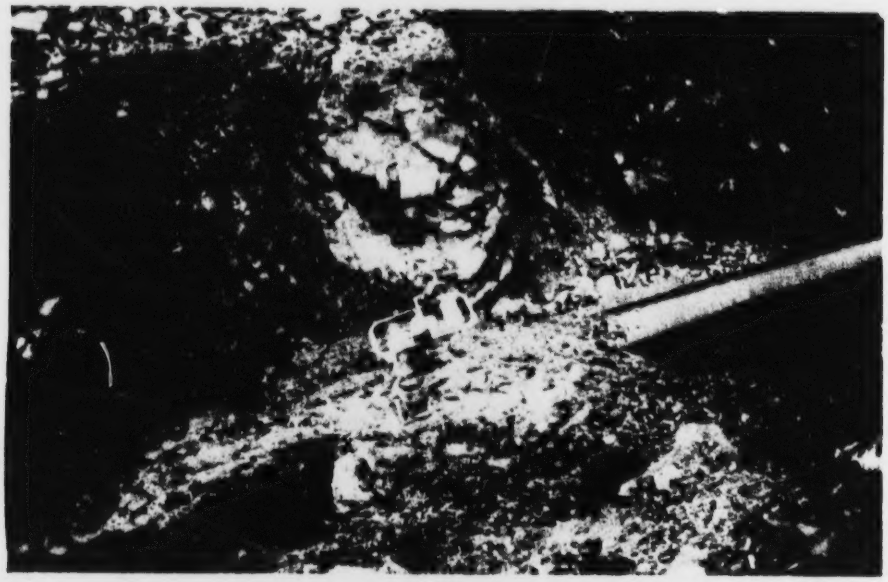


Figure 29

Backfilling and Tamping around the Penstock.

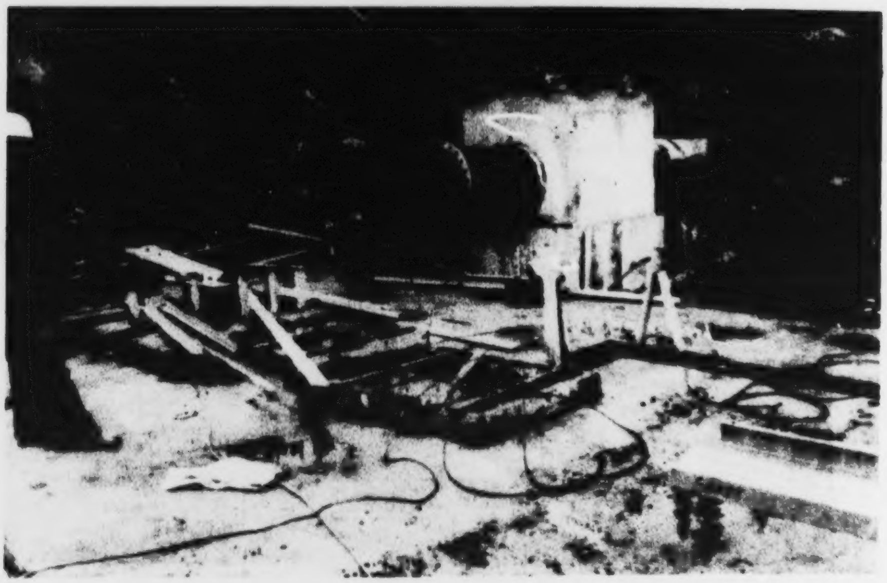


Figure 30

Penstock Anchor Block at Powerhouse

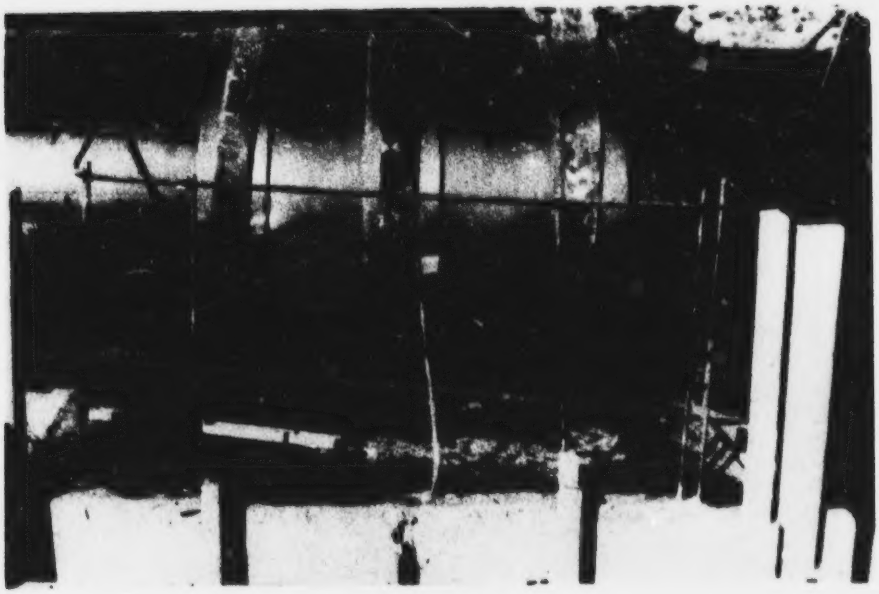


Figure 31

Anchor Block Detail. Rubber gasket and metal bands to improve bond between pipe and concrete.

Figure 32

Penstock at Downstream Face of Dam.
The intake and shut off valve were
housed in the body of the dam.

Backfill continued uphill from the powerhouse. A second penstock anchor block was dowelled into in situ rock at a relatively sharp bend 120 m upstream from the powerhouse. Drainage pipe was placed as backfill progressed uphill towards the dam to control natural runoff. Finally, to complete the installation, the backfill material was graded and the site cleaned up.

POWERHOUSE

Because the powerhouse site was so wet, engineers decided to backfill the required area and excavate for the foundations. Although water was still a problem, the amount was significantly reduced.

In September, excavation was carried out to the required level and ground conditions were found to be acceptable and to have good foundation bearing. Construction of the base slab and foundation walls proceeded with few problems except for dewatering. The powerhouse floor elevation required that the adjacent Marble Brook be excavated more than anticipated. This was accomplished as machinery became available.

The floor slab and the equipment pads were poured to the hydro equipment package supplier's requirements and the prefabricated metal building was in place before the machinery arrived. A communication problem between office and field resulted in the penstock at the powerhouse being installed 439 mm higher than the desired elevation. It was decided that the error could not be corrected without major remedial work and therefore the equipment pads were modified to compensate for the additional height of the penstock. This was completed before the equipment was ready for installation. When the supplier's representative arrived, he found that the supplier's original information had been insufficient and further minor pad modifications were required. These did not significantly alter scheduling.

The equipment was placed manually with few problems, aligned and grouted or anchored in position, at which point the substantial civil involvement ended.

As is often the case, the balance between improving information by more thorough initial site investigation against the cost of obtaining this information presents a dilemma that must be solved individually on each project and for each structure in the project. Improvements could be made in the planning stages and in better and more timely information from material and equipment suppliers. This would prevent delays, unnecessary modifications and the associated cost increases.

Figure 33

Power House Excavation Looking
Upstream along Route of Penstock.

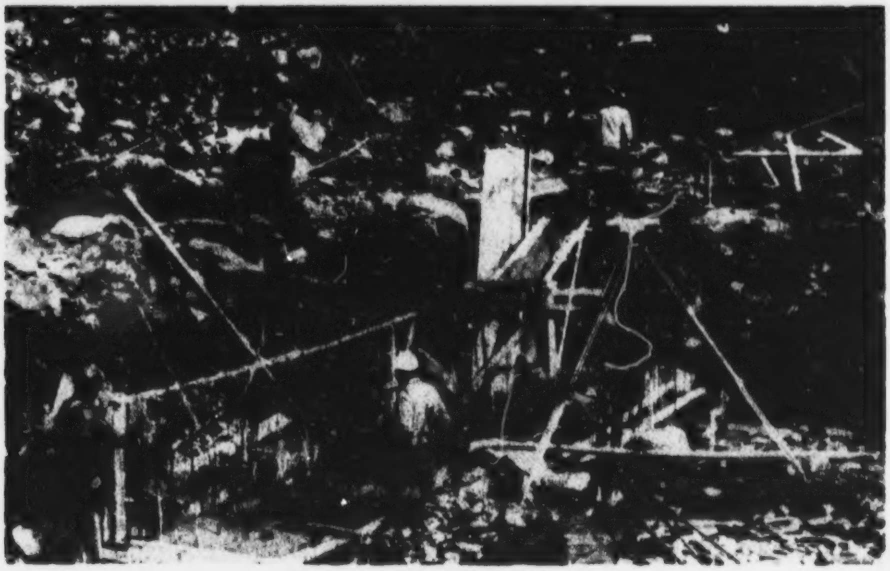


Figure 34

Pouring the Powerhouse Foundations.

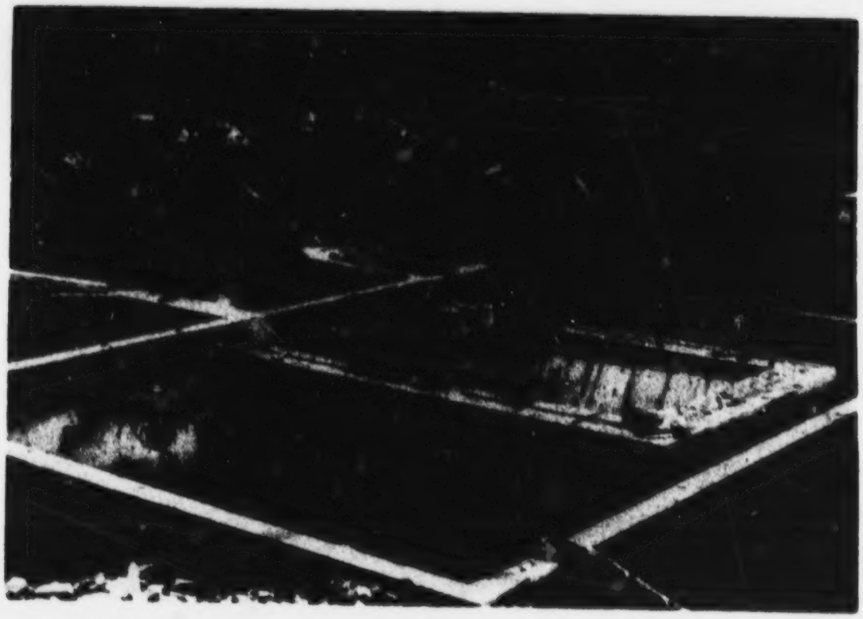


Figure 35

Powerhouse Foundation Walls Stripped.
Workmen are standing in tailrace area.

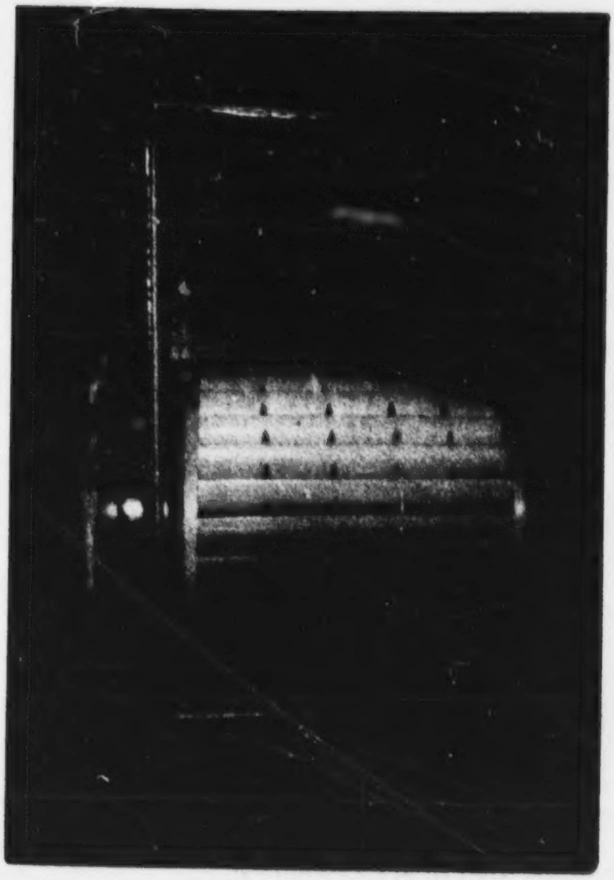


Figure 36

Housing Removed to Show Runner
of cross flow turbine.

The difficulties created by not having sufficient information from the turbine-generator supplier was one of the major obstacles in the powerhouse construction.

MECHANICAL-ELECTRICAL

Installation of Plant Equipment Package

To minimize cost, the tender specification for the generating equipment package permitted suppliers to quote on an "off the shelf" package, which would be accommodated within broadly defined parameters. Refinements to accommodate the unique features of the Roddickton site were not suggested by or anticipated from the supplier. In retrospect, the specific details of the generating equipment package should have been more closely defined as misunderstandings arose regarding the cost of some items.

The original scheduling promised delivery of the equipment package by 1 August 1980 and the planned program envisioned the powerhouse concrete foundations, equipment pads and anchors poured and the heavier equipment items (turbine package, 1930 kg, and generator package, 5330 kg) placed on their pads and suitably protected before the walls of the prefabricated building were erected. This would allow the use of boom cranes and would simplify erection since no powerhouse overhead crane or lifting device was included in the design. Late delivery of the various items of equipment made this regime unworkable. The building was therefore completed before the main equipment was installed. Moving the items into place required blocking, jacking and, therefore, more manhours than originally conceived. With this exception, the mechanical assembly of the generating equipment package proceeded without further difficulties since the unit assembly was simple and the concrete encasement straightforward.

Electrical and Telecontrol

Engineers had difficulty getting answers from the supplier to requests for information on the electrical wiring for the control board and also for the wiring interface with Telecontrol, and the site had to be modified continually to accommodate the necessary circuitry. This work was done concurrently with the mechanical installation. The unit was in operation on 10 December 1980 although fine tuning of the protection system continued beyond this date.

Figure 37

Interior of Powerhouse. From left to right – butterfly valve, transition piece, turbine, flywheel, speed increaser, generator. The unit control panel is in the background. The top portion of the governor is seen in back of the turbine.

Figure 38

Completed Plant, note Substation to Right of Powerhouse.

Although not a part of the cost-shared portion of the project, part of the existing Roddickton-Conche powerline had to be upgraded from a single-phase to three-phase and the Hydro site had to be connected to this system. This work was managed by employees of the Power Distribution District of Newfoundland and was constructed on schedule without any particular difficulties.

Engineering and erection of the site substation, which consists of three delta-star 167 kV A single-phase transformers and the usual protection, was completed by Hydro with field force assistance supplied by PDD. This installation transformed the site generation from 600 V to 12 500 V. Connection from the substation to the powerhouse cable trench was via buried conduits. A 600 V, 600 A breaker was installed in the electric control board. Station service was provided by a 37.5 kV A 600 V/120/240V transformer mounted on the wood pole substation structure and connected through a kWh meter for consumption records. Distribution transformers also were mounted at the dam and at the microwave antenna sites, and single-phase lines were constructed to these locations.

Telecontrol and communication circuits were provided to connect the Marble Brook Hydro plant with the existing Roddickton diesel plant. In addition to voice communication, control of the following functions was incorporated – stop unit, raise/lower kilowatts, raise/lower voltage. Indication of the following were also relayed back to the Roddickton diesel plant – head pond water level, kW output, power factor, voltage (600 V machine bus), breaker status (600 V breaker - opened/closed). Alarms also were part of the telecontrol package. Direct current requirements were supplied from a 48 V battery system and charger with 100 ampere-hours rating.

Problems were encountered with the hardware of the telecontrol and communications circuits, and the apparatus had to be removed and returned to the supplier for repair. Although the fault was minor, the logistics of installing equipment at relatively remote sites magnify the cost impact of any problem requiring shop repairs.

CONCLUSIONS

Schedule

Even if construction of a mini-hydro project in a single season seems possible, two-seasons are recommended as they allow time to uncover and solve some unanticipated problems, refine scope, tender long-delivery items, gather support, access and resources, and to re-evaluate original planning.

Logistics

The logistics of supplying a remote hydro site demand careful attention to quantity estimates, purchasing and expediting. Although a project may be simple in both content and size, the need for strict cost control requires very detailed material requirement lists, and sincere, realistic delivery promises, which must be strictly monitored. The cost of missing or late materials or equipment components is magnifield in an area that is difficult to reach, where local facilities to make modifications or improvements are few. The cost-monitoring system should be simple and able to indicate trends quickly.

OPERATIONAL CONSIDERATIONS

In keeping with the screening methodology employed for site selection for small-scale hydro, as outlined in the study of small-scale hydro for Newfoundland and Labrador Hydro[4], this development is located near an isolated diesel system. The project site is within five km of the Roddickton diesel plant, which services a system peak demand (1980) of 1700 kW and an energy demand (1980/81) of 6 000 000 kWh. The development contributes a net generation of 400 kW and annual energy of 1 500 000 kWh.

Because the diesel plant was so near, the staff of five operators, backed up by regional support staff, did not have to be increased. To obtain the necessary exposure to and understanding of the operation, equipment and systems, the chief operator was involved in the on-site erection activities from the start and so, to a lesser extent as required, were the regional technical support staff. When the development was completed, the chief operator trained the other operators with assistance from other corporation employees.

For reasons of economy a mini-supervisor system was implemented, whereby VHF radio link provides the diesel plant operation with control options of shutting down the unit, raising and lowering the kW and kVAR output of the plant; indication of kW, power factor, voltage and head pond water elevation; and some basic alarms.

The mini-hydro plant is a run-of-the-river operation directed towards production of maximum average annual energy. For economic reasons the unit was not sized to accommodate the full anticipated spring freshet of each year, and yet the correlated hydrology indicates very low in-flows through some winter months. Because a minimal flow of 200 L/s is maintained because of salmon spawning, efficient operation will require skillful manipulation of the head pond level, which will vary over a range of 1m.

The cross-flow turbine is particularly adaptable to this type of operation. Its essentially flat efficiency curve operates close to 80 % efficiency down to 15 % of the gate by employing two guide vanes in a 2:1 ratio. Although no means of measuring flow were available during commissioning, it is intended to conduct efficiency tests in near future.

The turbine does not employ an automatic air inlet valve in the housing to regulate tail water level, but evaluation after installation, reflecting subsequent adjustments to elevation, indicated the possibility of an economic head gain of up to 1.5 m. This possibility is currently under study.

Start-up and synchronization of the unit is manual only. The Woodward governor pump assembly employs a manual cranking operation to bring the unit initially up to synchronous speed – no load. Frequent starts and stops of the unit should not be required, thereby keeping operational costs to a minimum.

The overcurrent, undervoltage, over and under frequency and reverse power protection are assured by simultaneously initiating, from a protection trip, a complete governor shutdown (vanes fully closed) as well as the unit butterfly valve closure. The runaway speed of the unit is close to 100 % above synchronous speed and the turbine (451 r/min), generator (1200 r/min) and speed increaser components accommodate in their design considerable sustained overspeed operation.

The development uses 440 m of 800 mm nominal diameter polyethylene pipe as the pressure conduit. Engineers considered leaving the pipe water up during periodic winter shutdowns, and providing a minimum earth cover of 500 mm above the pipe as well as providing sufficient insulation at the intake well and the entrance through the powerhouse wall. Vane closing times were calculated by the pipe supplier through computerized simulation. Refinement during plant commissioning resulted in a 16 s governor time for full flow and head conditions. The pressure conduit can be drained by a manually operated intake valve. This intake section also provides for stop logs as well as the vacuum breaker valve for draining and filling operations.

The unit components do not require skilled maintenance other than occasional lubrication and periodic visual inspection. A log has been instituted to record intervals and dates between maintenance jobs. Sufficient quantities of governor and speed increaser fluids are kept on hand as well as spare parts such as ball bearings, speed increaser gears and voltage regulator and rectifier.

The spillway is a lowered and planked section of the rock-filled timber crib dam. It is sized to accommodate a 1 in 100 year flood. A water release pipe is also provided through the dam to maintain fisheries compensation and downstream town water reservoirs, if required.

During the winter the site will normally be reached by skidoos unless circumstances necessitate opening up the 1.5 km access road. Site security is maintained by a suitable gate at the entrance to the access road to restrict vehicular traffic. The pre-engineered building and upstream structure have suitable warning signs posted but there are no security fences. Procedures have been set up to record operating data such as energy output and to verify the actual performance of the demonstration project.

RODDICKTON MINI HYDRO
PROJECT DATA

PROJECT PARAMETERS

Drainage area	23	km^2
Reservoir surface area	0.3	km^2
Operating levels		
F.S.L.	135.0	m
L.S.L.	133.7	m
Average flow	0.7	m^3/s
Power capacity	440	kW
Energy	1 500 000	kWh/a
Capacity factor	40%	
Gross head	46.9	m

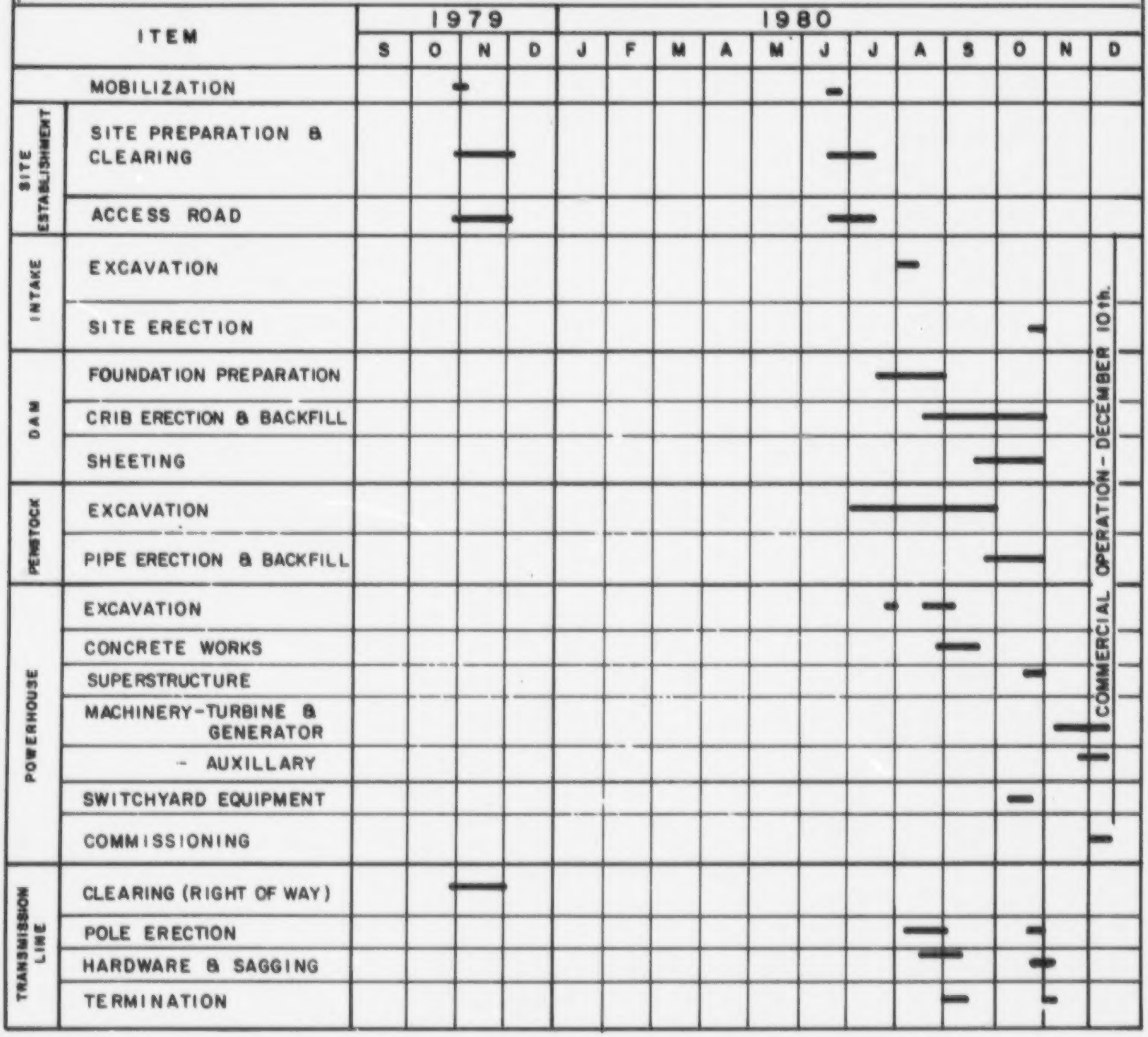
MAJOR EQUIPMENT

Turbine	-	Ossburger 440 kW, 42 m net head, 1290 L/s, 451 r/min
Generator	-	Kato 531.25 kV·A, 600 Volt, 60 Hz, 1200 r/min
Governor	-	Woodward UG2
Penstock	-	DuPont, polyethylene nominal 800 mm, series 45,60 and 80, 440 m
Intake	-	Bellmouth 10 mm plate 1.5 m x 2.0 m x 1.5 m
Powerhouse	-	Armco, pre-engineered, 6 m x 8.5 m x 3 m
Dam structure	-	Timber crib, 200 mm x 200 mm, rock filled, upstream faced with two layers of plank 52 mm inner, 25 mm outer, length 70.3, width to 3.98 m to 5.18 m, greatest height 3.4 m.

RODDICKTON MINI – HYDRO DEVELOPMENT
MANPOWER STATUS REPORT
FINAL

CLASSIFICATION	CUMULATIVE MANHOURS TO APRIL 1981
FIELD:	
Labourers	11 743.5
Carpenters	3 649.0
Truck drivers (equipment rentals)	1 554.0
Operators (equipment rentals)	4 440.0
Foremen	2 452.0
Office clerk	1 320.0
Engineer	857.5
Superintendent	960.0
SUBTOTAL	26 976.0
ST. JOHN'S ENGINEERING & CONSTRUCTION MANAGEMENT:	
Civil design	1 612.0
Mechanical design	62.0
Electrical design	913.0
Management	71.5
Drafting - as built	95.5
TELECONTROL	116.5
PROJECTS CONTROL	575.0
CONSTRUCTION MANAGEMENT	310.0
SUBTOTAL	3 755.5
TOTAL	30 731.5

ACTUAL CONSTRUCTION SCHEDULE FOR RODDICKTON HYDRO DEVELOPMENT



1. Project Cost Data: (projected final costs)

(a) Major Equipment Purchases:

Hydraulic turbine/generator and control package	$ 252 100	
Penstock	99 800	
Powerhouse superstructure	17 200	
Intake structure	14 400	
Dam Materials	97 100	
Substation	16 100	
Miscellaneous electrical	22 500	
Total		$ 519 200

(b) Field Construction:

Access roads (2.1 km)	83 400	
Installation of:		
Controls	5 000	
Turbine/generator	11 300	
Penstock	166 700	
Powerhouse	39 300	
Intake	6 800	
Intake canal excavation	20 400	
Dam construction	106 000	
Substation	1 200	
Miscellaneous electrical	12 000	
Transmission line from powerhouse to dam	20 300	
Total		$ 472 400

(c) Engineering and Construction Management:

Direct Costs:		
Engineering	59 800	
Telecontrol	3 000	
Projects control	16 700	
Construction	66 000	
Indirect Costs:		
Survey	43 000	
Hydrological study	2 300	
Drawings	1 900	
Total		$ 192 700

(d)	Corporate Overhead and Project Insurance	$ 14 600
(e)	Interest During Construction	$ 14 500
(f)	Contigency	$ 11 600
	Total Gross Project Costs	$1 225 000

REFERENCES

1. Report on Turbo Generating Equipment for Low Head Hydro-Electric Developments; W. K. VerPlanck and W.W. Wayne, Jr., both of Stone and Webster Engineering Corporation; April, 1978.

2. Hydro-Electric Handbook; Craeger and Justin; 1950.

3. Engineering Practice in Hydro-Electric Projects; Brown.

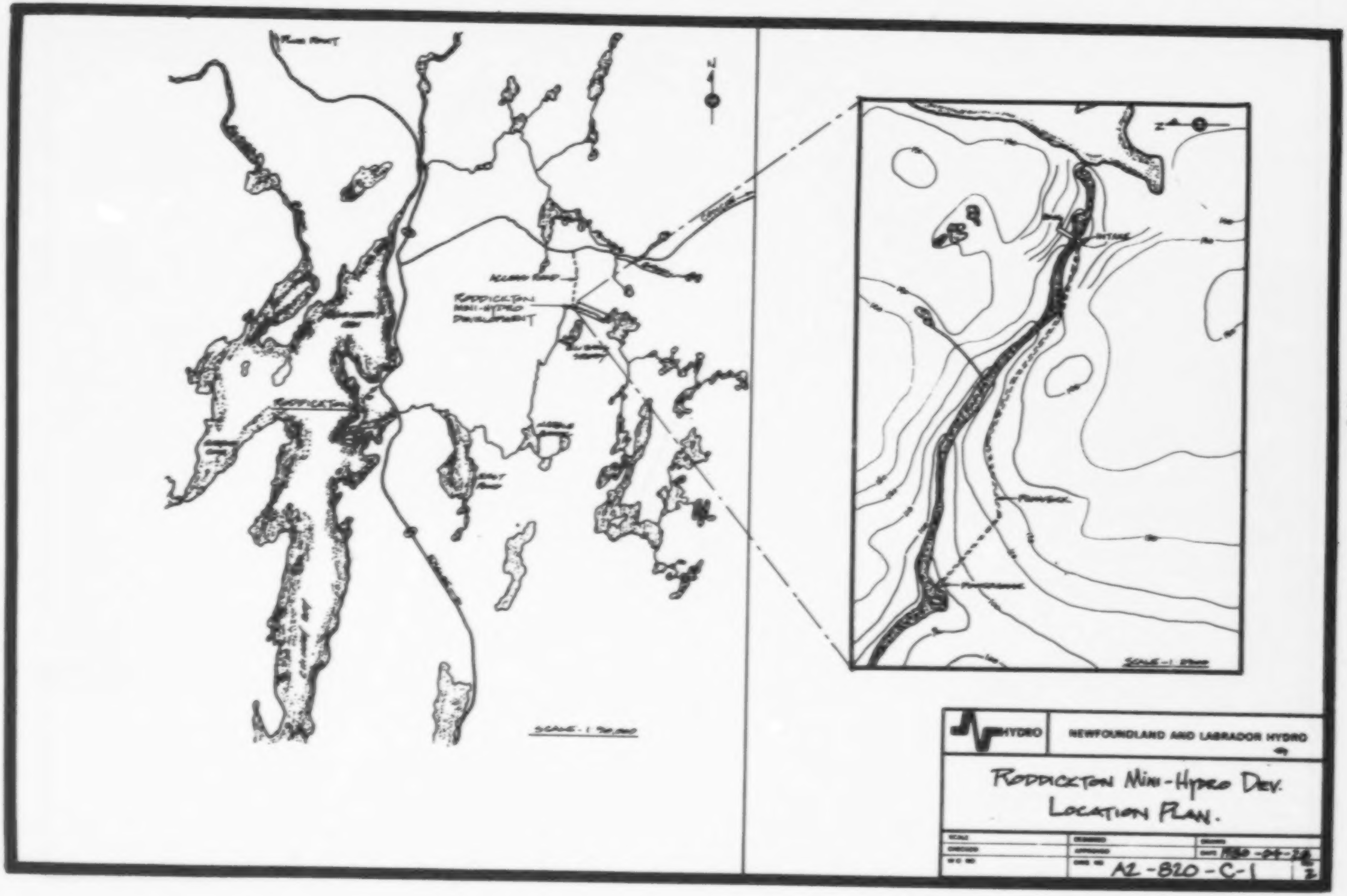
4. Study of Small Scale Hydro for Newfoundland and Labrador Hydro by ShawMont Newfoundland Limited dated 1979-03-23.

5. Matching Flow and Load: Sizing Hydro-Electric Plants to Serve Isolated Communities; Phinney, R.B.; Fourth CSCE Atlantic Region Hydrotechnical Conference, St. John's, Newfoundland, June 1980.

6. Small Hydro Sets Can Yield Competitive Energy; Gordon, J.L.; Energy International, August, 1978.

APPENDIX A

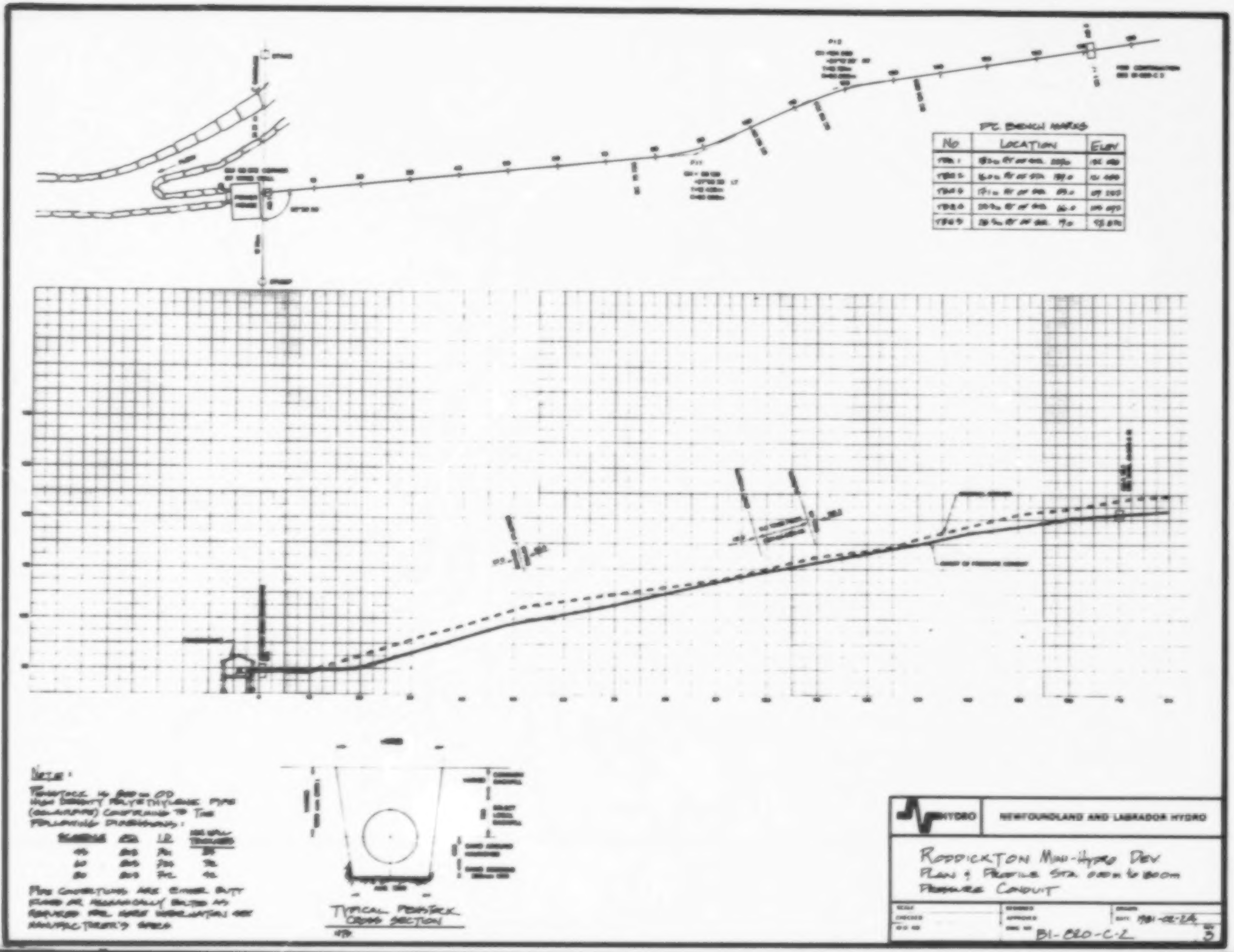
CONSTRUCTION DRAWINGS


N
Roddickton Mini-Hydro Development
Roddickton
Intake
Penstock
Powerhouse
HYDRO

NEWFOUNDLAND AND LABRADOR HYDRO

RODDICKTON MINI-HYDRO DEV.
LOCATION PLAN.

DATE 1980-04-28
DWG NO A2-820-C-1


PC BENCH MARKS
No
LOCATION
ELEV
NOTE:
TYPICAL PENSTOCK CROSS SECTION
HYDRO
NEWFOUNDLAND AND LABRADOR HYDRO
RODDICKTON MINI-HYDRO DEV
PLAN & PROFILE STA. 0+00m to 800m
PRESSURE CONDUIT
DATE 1981-02-24
B1-820-C-2
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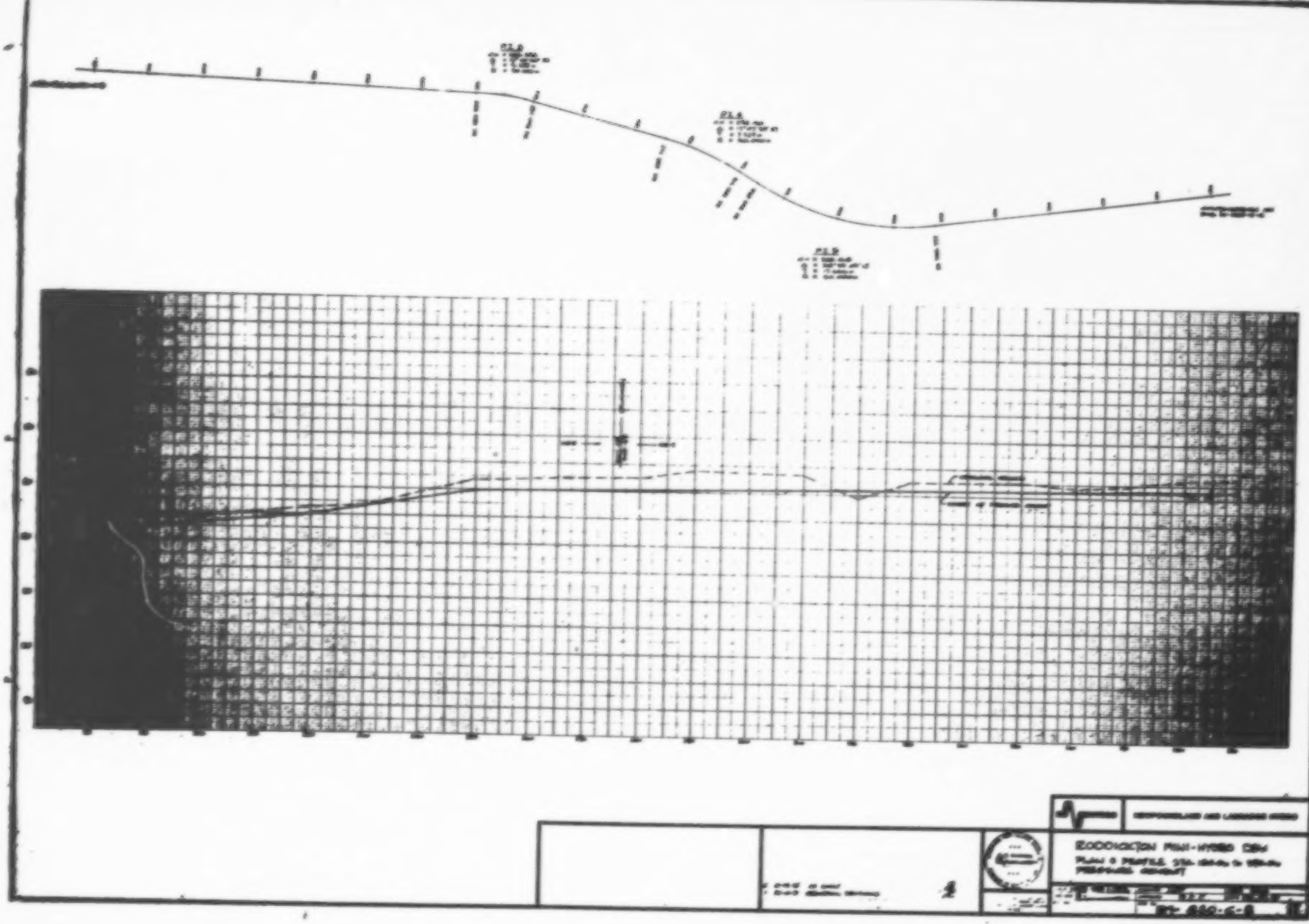
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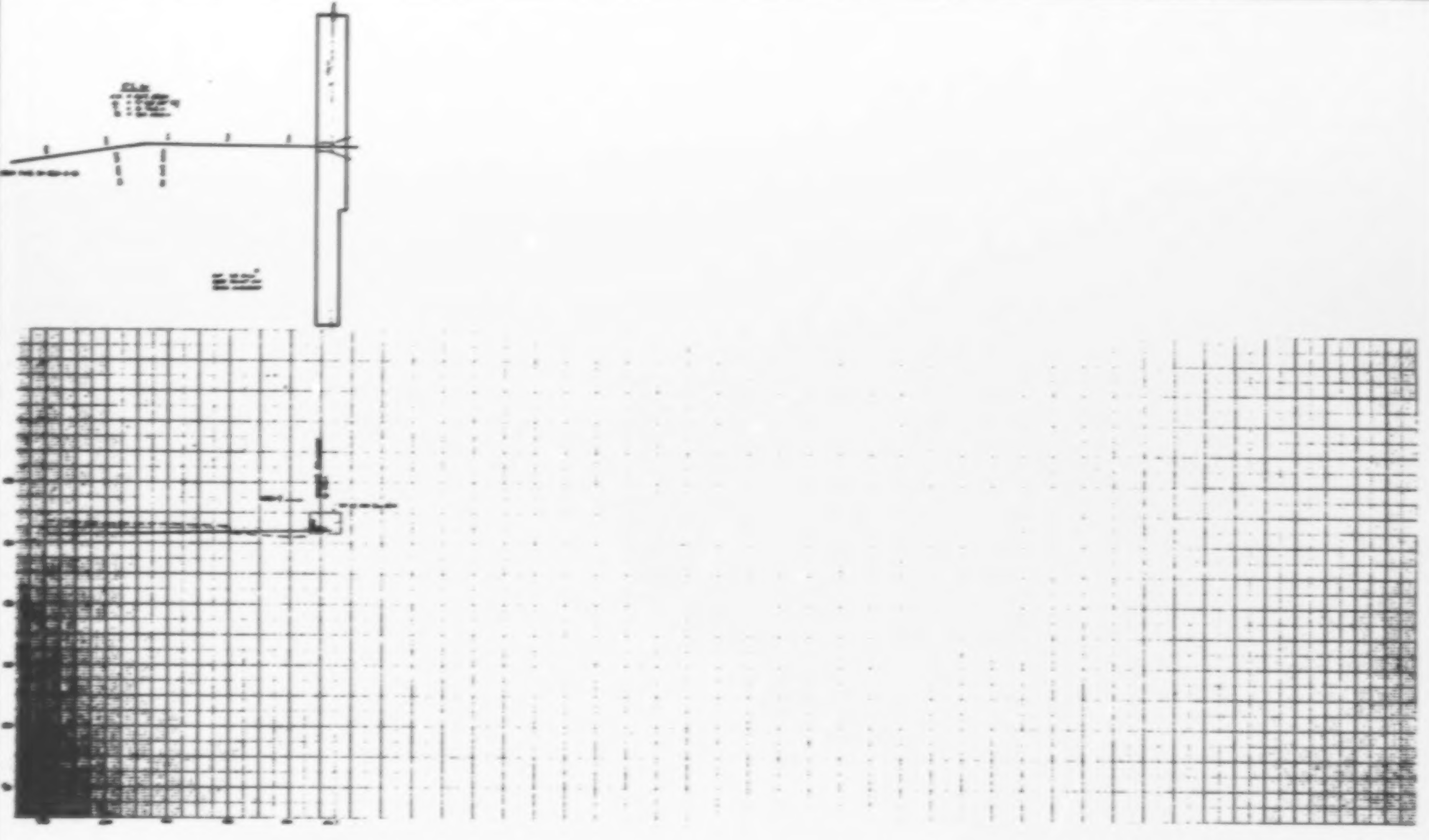
PLAN & PROFILE



NEWFOUNDLAND AND LABRADOR HYDRO

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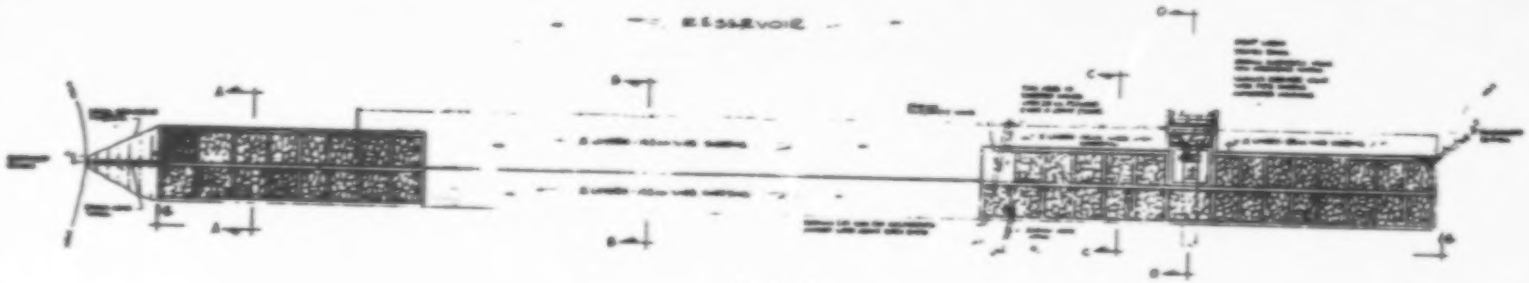
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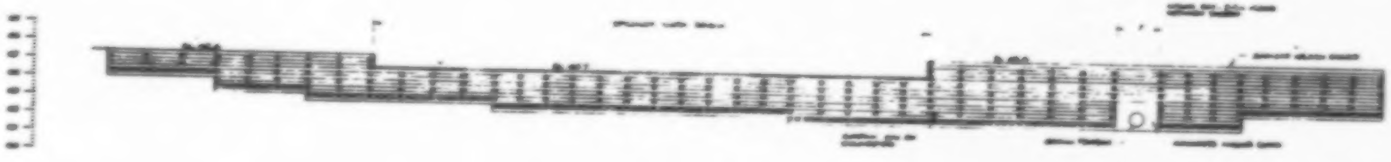
PLAN



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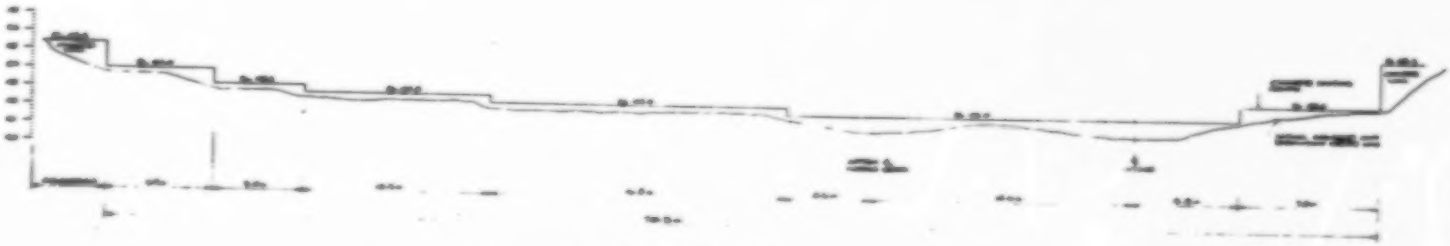
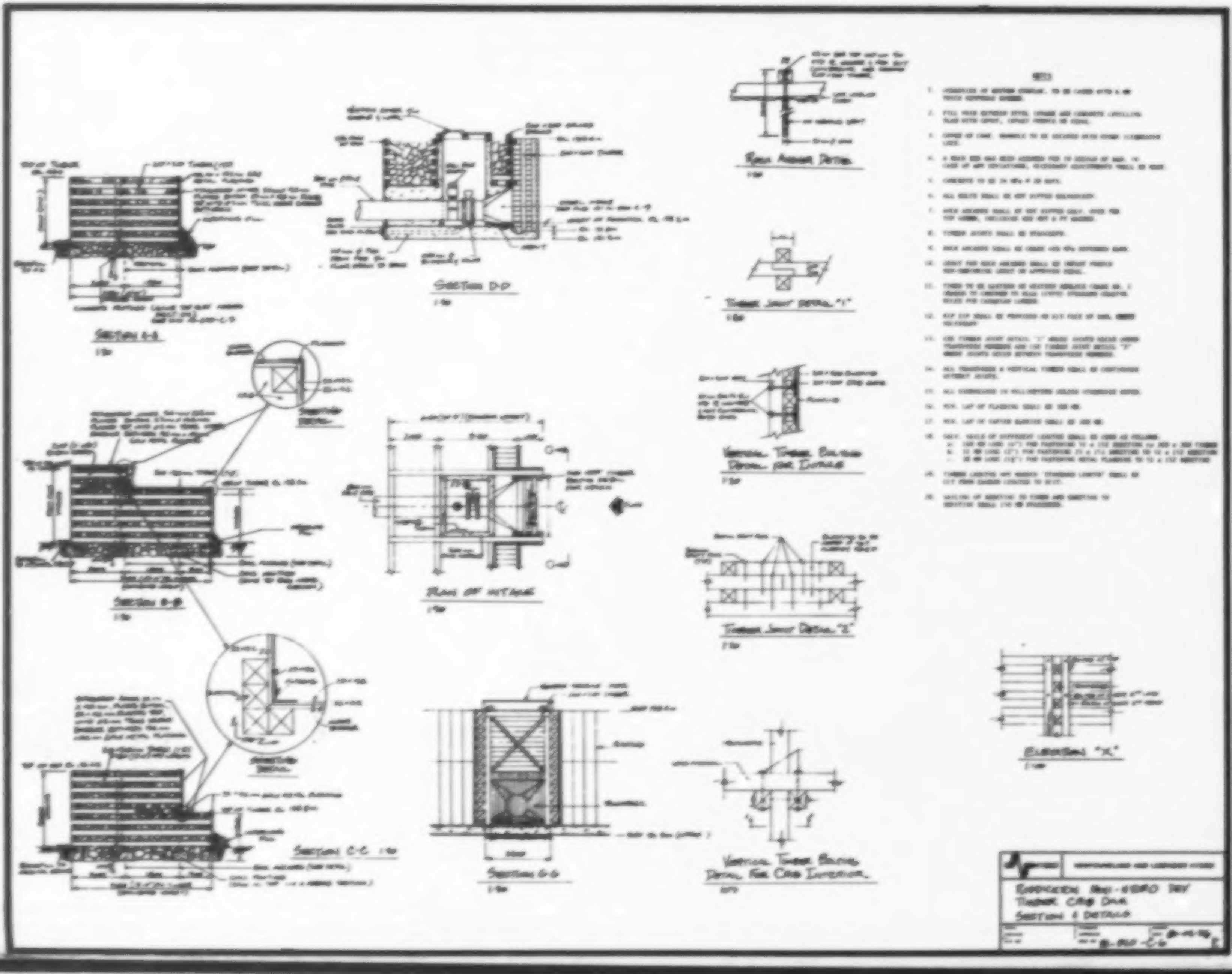
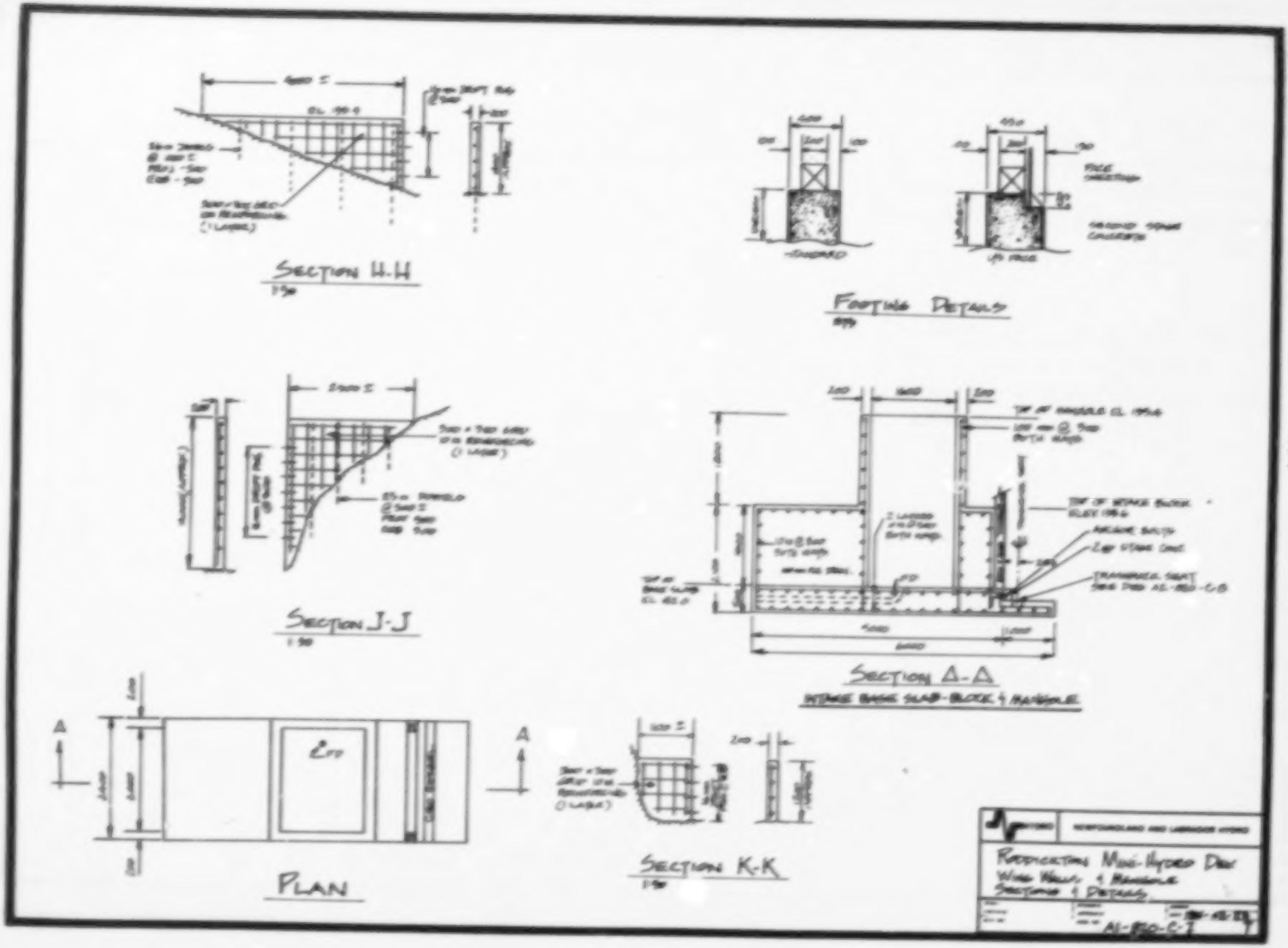


ROCK EXCAVATION & CONCRETE GRADE LINE

[illegible] MINI-HYDRO DEV.
TIMBER CRIB DAM &
EXCAVATION GRADE LINE

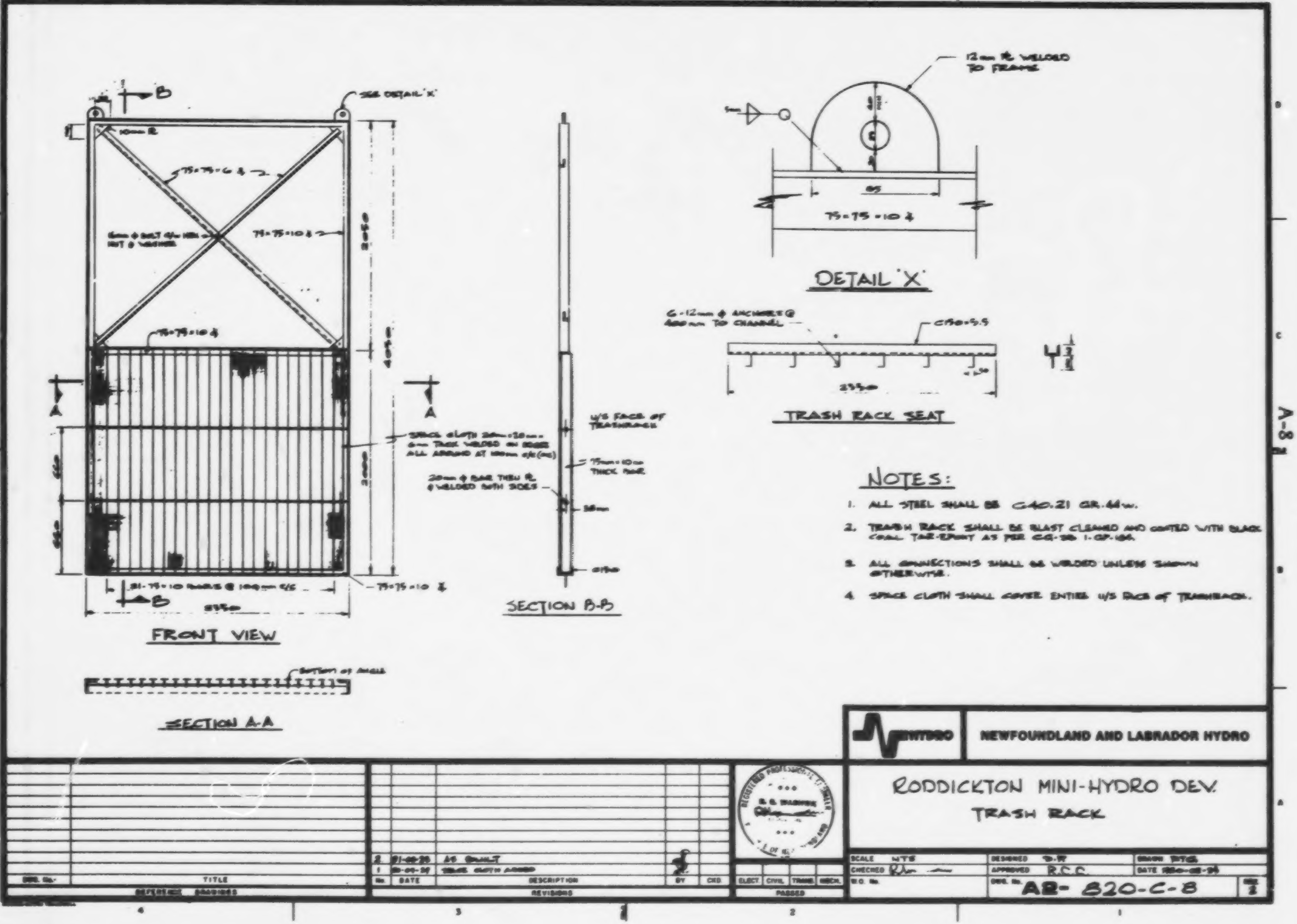

SECTION A-A
SECTION D-D
ROCK ANCHOR DETAIL
NOTES
TIMBER JOINT DETAIL "1"
SECTION B-B
PLAN OF INTAKE
VERTICAL TIMBER BOLTING DETAIL FOR INTAKE
TIMBER JOINT DETAIL "2"
SECTION C-C
SECTION G-G
VERTICAL TIMBER BOLTING DETAIL FOR CRIB INTERIOR
ELEVATION "X"
RODDICKTON MINI-HYDRO DEV
TIMBER CRIB DAM
SECTIONS & DETAILS


SECTION H-H
1:50
FOOTING DETAILS
SECTION J-J
1:50
SECTION A-A
INTAKE BASE SLAB-BLOCK & MANHOLE
PLAN
A
A
SECTION K-K
1:50

NEWFOUNDLAND AND LABRADOR HYDRO

Roddickton Mini-Hydro Dam
Wing Walls & Manhole
Sections & Details

A1-850-C-7


SEE DETAIL 'X'
B
10mm R
75×75×6 L
6mm ϕ BOLT c/w HEX NUT & WASHER
75×75×10 L
2050
75×75×10 L
4050
A
A
SPACE CLOTH 20mm×20mm 6mm THICK WELDED ON EDGES ALL AROUND AT 100mm c/c (MAX)
2000
650
650
21-75×10 BARS @ 100mm c/c
75×75×10 L
2330
B
FRONT VIEW
BOTTOM OF ANGLE
SECTION A-A
U/S FACE OF TRASHRACK
75mm×10mm THICK BAR
20mm ϕ BAR THRU PL & WELDED BOTH SIDES
38mm
150
SECTION B-B
12mm PL WELDED TO FRAME
85
75×75×10 L
DETAIL 'X'
6-12mm ϕ ANCHORS @ 400mm TO CHANNEL
C150×5.5
2330
TRASH RACK SEAT

NOTES:

1. ALL STEEL SHALL BE G40.21 GR.44W.
2. TRASH RACK SHALL BE BLAST CLEANED AND COATED WITH BLACK COAL TAR-EPOXY AS PER CGSB 1-GP-186.
3. ALL CONNECTIONS SHALL BE WELDED UNLESS SHOWN OTHERWISE.
4. SPACE CLOTH SHALL COVER ENTIRE U/S FACE OF TRASHRACK.

No.	DATE	DESCRIPTION	BY	CKD
2	81-08-28	AS BUILT		
1	80-09-29	SPACE CLOTH ADDED		

REVISIONS

DWG. No.	TITLE

REFERENCE DRAWINGS

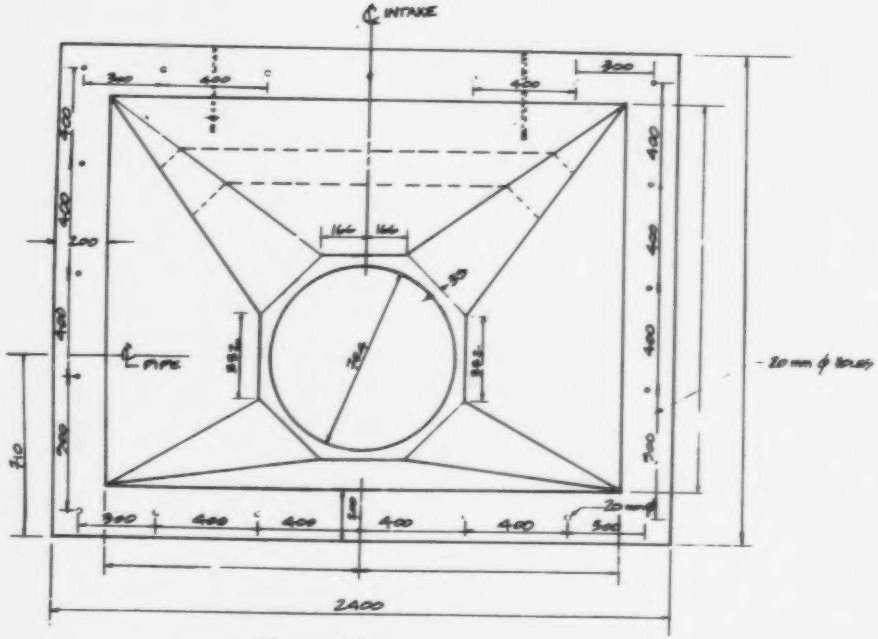
ELECT. CIVIL TRANS. MECH.
PASSED

R. G. WARWICK

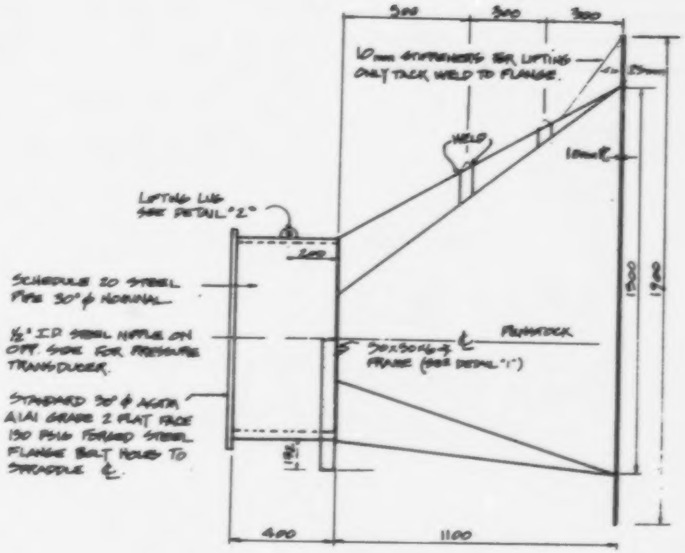
NEWFOUNDLAND AND LABRADOR HYDRO

RODDICKTON MINI-HYDRO DEV.
TRASH RACK

SCALE	NTS	DESIGNED	D.W.	DRAWN	BTG
CHECKED		APPROVED	R.C.C.	DATE	1980-08-29
W.O. No.		DWG. No.	AB- 820-C-8	REV.	2

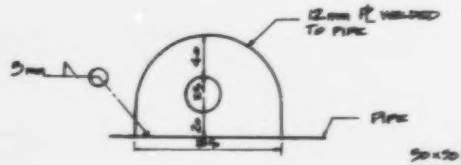

℄ INTAKE
300
400
300
400
400
400
200
400
200
166
166
50
762
352
352
℄ PIPE
710
300
400
400
400
400
300
20mm
400
400
400
300
2400
20 mm ϕ HOLES

FRONT VIEW


300
300
300
10mm STIFFENERS FOR LIFTING ONLY TACK WELD TO FLANGE.
25mm
WELD
10mm PL
LIFTING LUG SEE DETAIL "2"
200
SCHEDULE 20 STEEL PIPE 30" ϕ NOMINAL
½" I.D. STEEL NIPPLE ON OPP. SIDE FOR PRESSURE TRANSDUCER.
50x50x6.4 ∟ FRAME (SEE DETAIL "1")
℄ PENSTOCK
STANDARD 30" ϕ ASTM A181 GRADE 2 FLAT FACE 150 PSIG FORGED STEEL FLANGE BOLT HOLES TO STRADDLE ℄.
195
1500
1900
400
1100

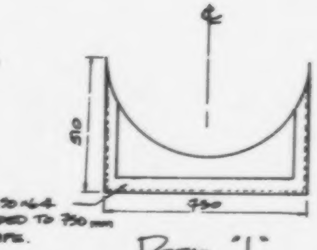
SIDE VIEW

OPPOSITE SIDE SIMILAR


12mm PL WELDED TO PIPE
5mm
40
50
20
PIPE

DETAIL "2"

NTS


℄
510
750
50x50x6.4 WELDED TO 750 mm ϕ PIPE.

DETAIL "1"

NTS

NOTES

1. ALL STEEL SHALL BE G40.21 GR. 44W
2. ALL SEAMS SHALL BE SEAL WELDED.
3. INTAKE SHALL BE BLAST CLEANED AND COATED WITH COAL TAR-EPOXY (BLACK) AS PER CGSB 1-GP-184.
4. BOLT HOLES IN FLANGE SHALL BE 20 mm DIA.
5. ALL PL SHALL BE 10mm THICK UNLESS NOTED.
6. ALL WELDS SHALL BE 8mm UNLESS NOTED.
7. STEEL FLANGE SHALL BE STANDARD 28 BOLT HOLE ARRANGEMENT.

HYDRO | NEWFOUNDLAND AND LABRADOR HYDRO

RODDICKTON MINI-HYDRO DEV.

STEEL INTAKE

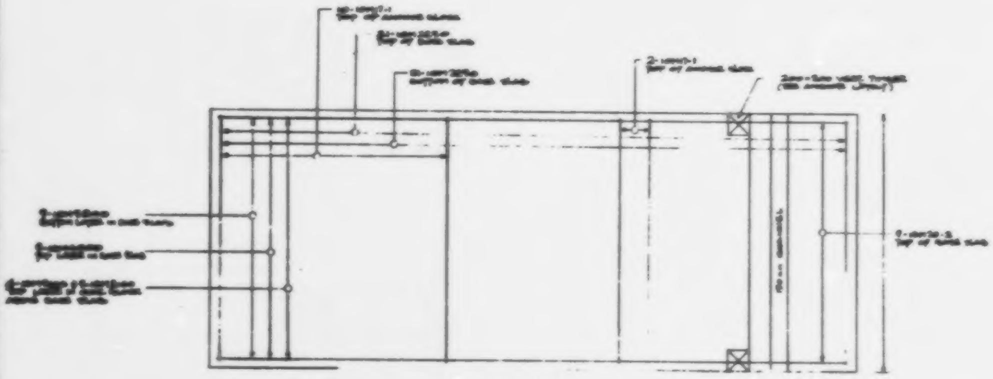
DATE 80-02-14

DWG NO AI-880-C-9

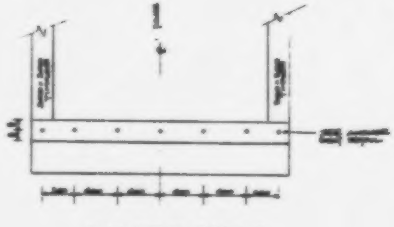
2

NOTES:

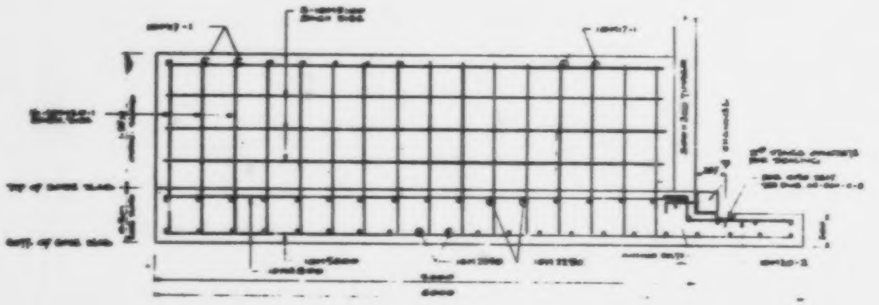
1. [illegible]
2. [illegible]
3. [illegible]
4. [illegible]
5. [illegible]
6. [illegible]
7. [illegible]
8. [illegible]



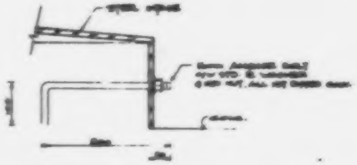
PLAN
1:20



ANCHOR BOLT LAYOUT
1:20



ELEVATION
1:20

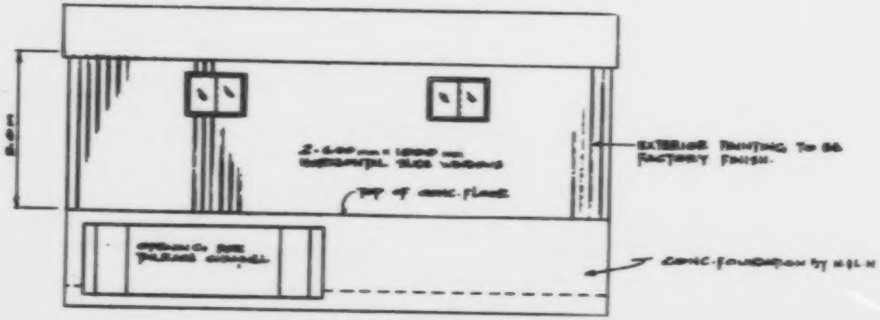


ANCHOR BOLT DETAIL
1:5

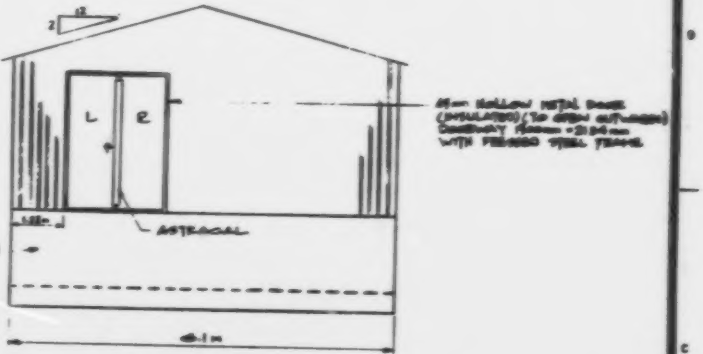
NEWFOUNDLAND AND LABRADOR HYDRO

RODDICKTON MINI-HYDRO DEV.
CONC. BASE SLAB AT INTAKE
PLAN, ELEVATION & DETAILS

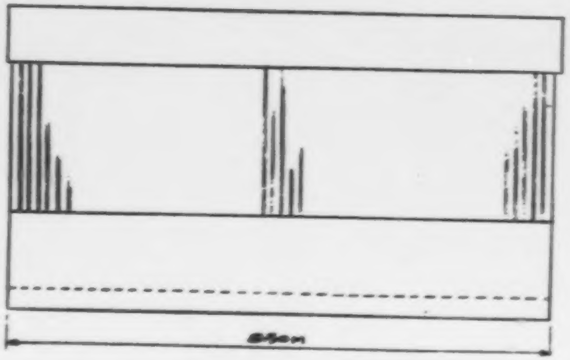
A1- 820-C-10


2 - 600mm × 1200mm
HORIZONTAL SLIDE WINDOWS
EXTERIOR PAINTING TO BE FACTORY FINISH.
TOP OF CONC. FLOOR
CONC. FOUNDATION BY N & L H

FRONT VIEW


12
2
L
R
ASTRAGAL
HOLLOW METAL DOOR (INSULATED) (TO OPEN OUTWARD) WITH PRESSED STEEL FRAME

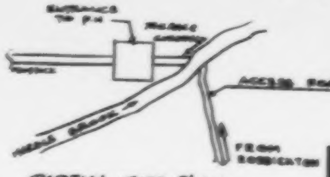
END VIEW
(ENTRANCE TO BUILDING)



REAR VIEW

NOTES

1. SLIGHT ALTERATIONS OF DIMENSIONS TO FIT STANDARD BUILDING ARE PERMISSIBLE.
2. FOUNDATIONS TO BE CONSTRUCTED BY N & L.H.
3. ERECTION OF BLDG. SHALL BE DONE BY N & L.H.
4. FOR FOUNDATION DETAILS SEE DWG. 84-820-C-12


ENTRANCE TO P.H.
ACCESS ROAD
FROM RODDICKTON

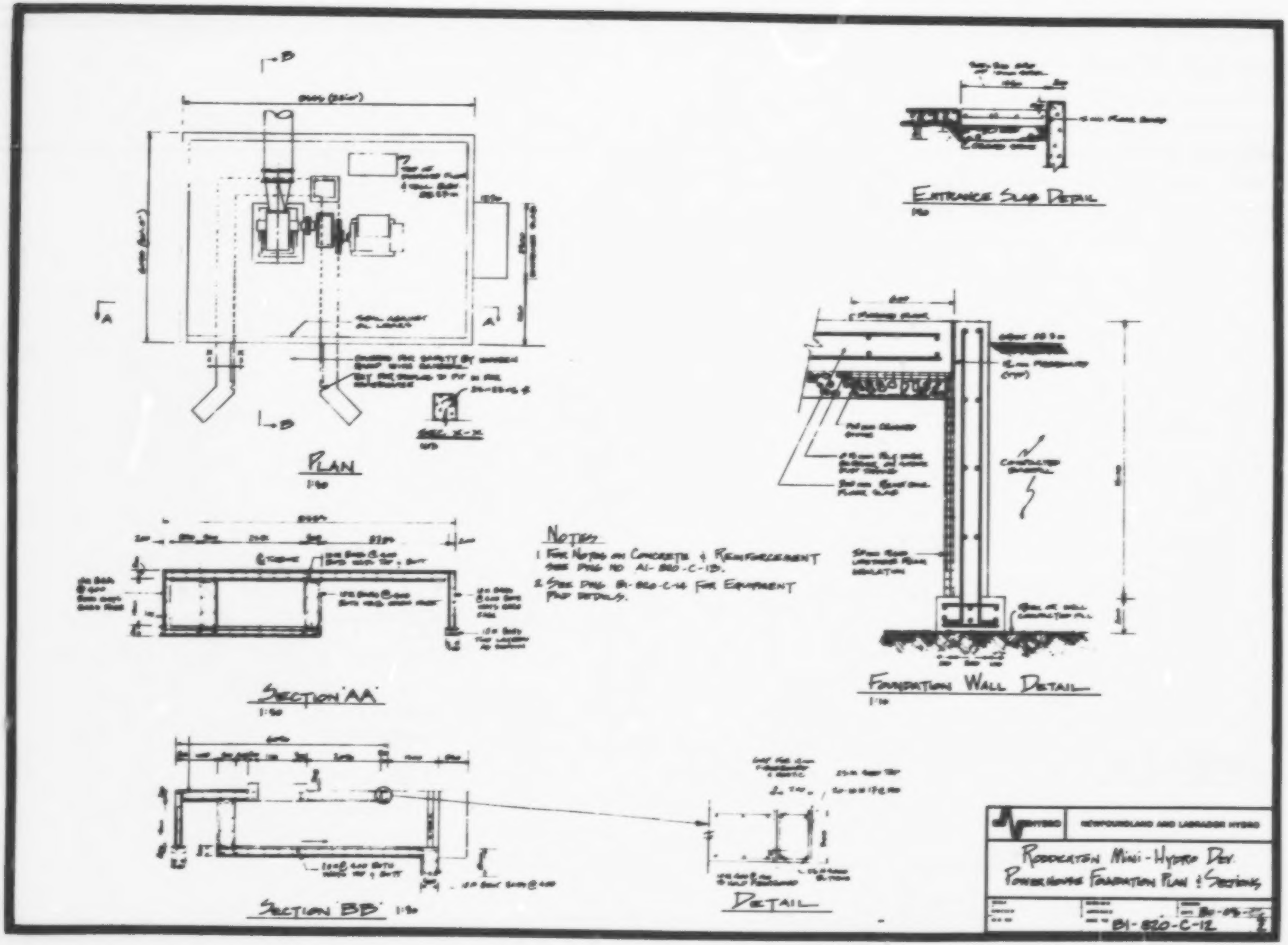
PARTIAL SITE PLAN

NEWFOUNDLAND AND LABRADOR HYDRO

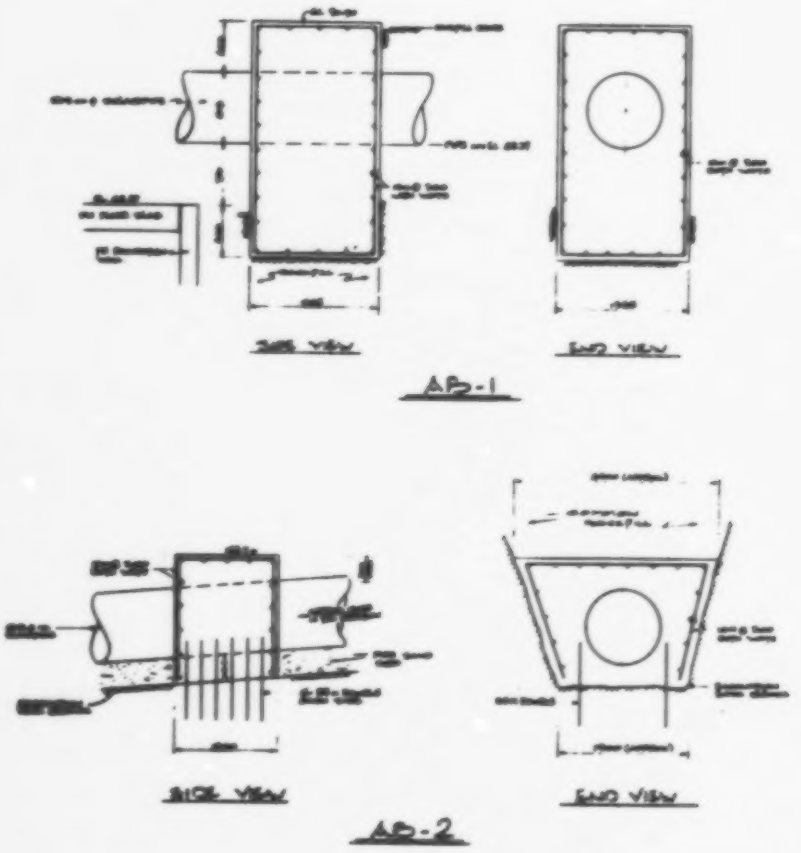
RODDICKTON MINI - HYDRO DEVELOPMENT
POWERHOUSE (PRE-ENGINEERED BUILDING)

SCALE N.T.S.
CHECKED
DESIGNED D. Pike
APPROVED R.C.C.
DRAWN
DATE
DWG No. AB- 820-C-11
REV 2

NO	DATE	DESCRIPTION	BY	CHD
2	[illegible]	AS BUILT		
1	[illegible]	GENERAL REVISIONS		


Plan
1:50
Sec. X-X
Section 'AA'
1:50
Section 'BB' 1:50
Detail
Entrance Slab Detail
1:10
Foundation Wall Detail
1:10
Newfoundland and Labrador Hydro
Roddickton Mini-Hydro Dev.
Powerhouse Foundation Plan & Sections
B1-820-C-12

Notes
1 For Notes on Concrete & Reinforcement see Dwg No A1-820-C-13.
2 See Dwg B1-820-C-14 for Equipment Pad details.


SIDE VIEW
END VIEW
AB-1
SIDE VIEW
END VIEW
AB-2

NOTES:

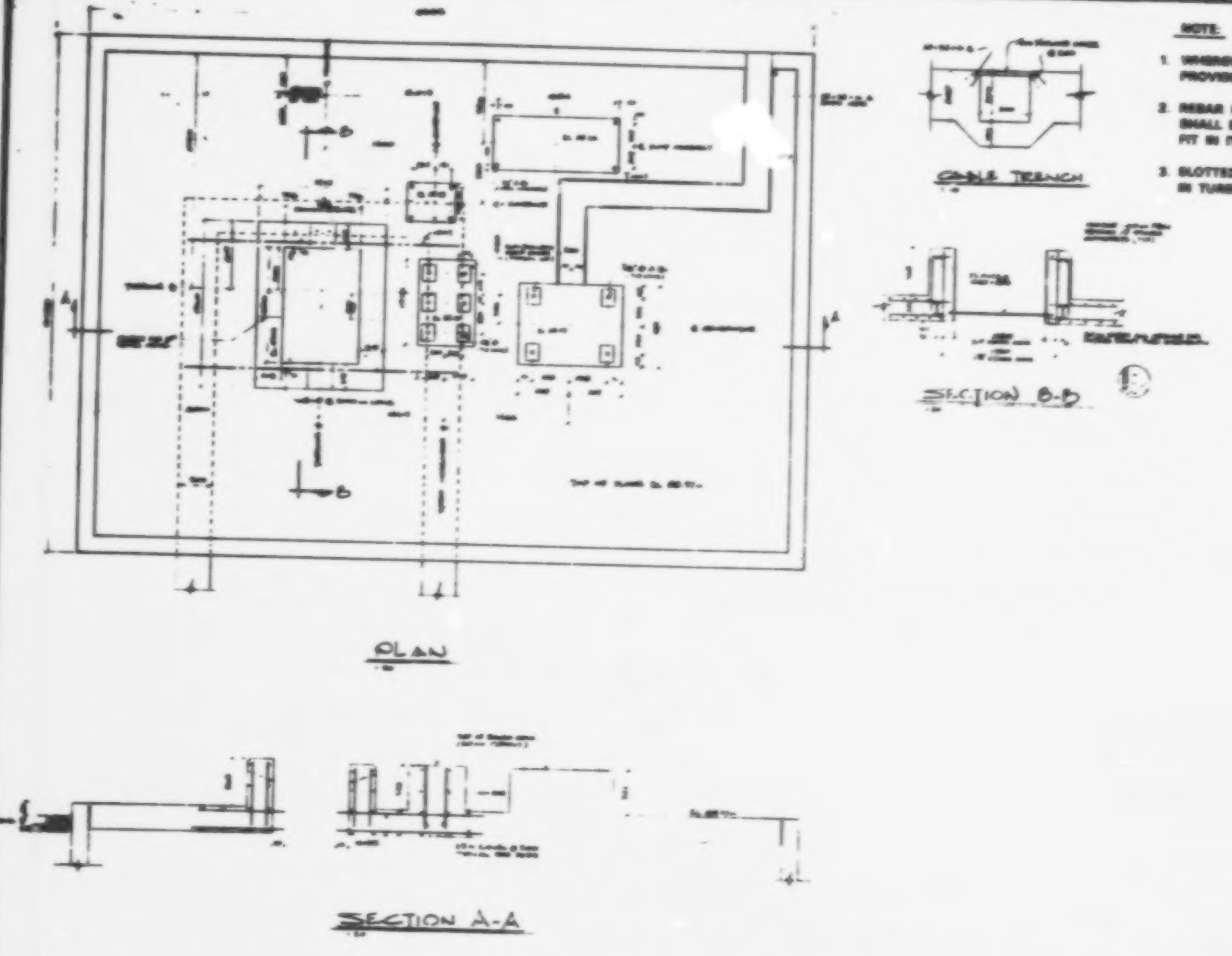
1. [illegible]
2. [illegible]
3. [illegible]
4. [illegible]
5. [illegible]
6. [illegible]
7. [illegible]
8. [illegible]
9. [illegible]
10. [illegible]
11. [illegible]

NEWFOUNDLAND AND LABRADOR HYDRO

[illegible] MINI-HYDRO DEM

ANCHOR BLOCK DETAILS

82-690-C-13

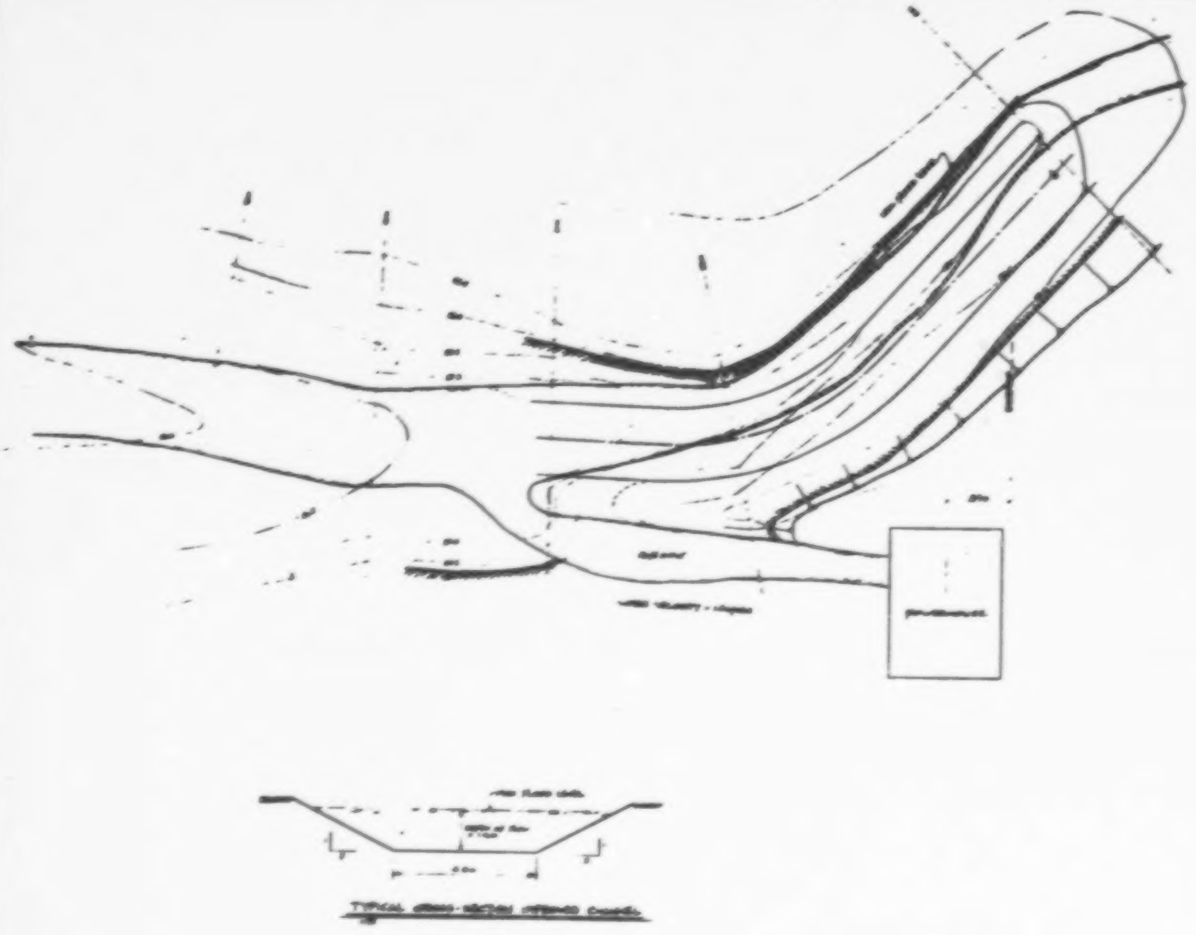

PLAN
SECTION A-A
CABLE TRENCH
SECTION B-B
A
A
B
B

NOTE:

1. WHEREVER CALLED FOR 20mm GROUT SHALL BE PROVIDED FOR EQUIPMENT SETTING
2. REBAR PROJECTING FROM 1st STAGE CONCRETE SHALL BE BENT AS REQUIRED TO MAKE DRAFT TUBE FIT IN ITS POSITION
3. SLOTTED A.B. POCKETS ARE PROVIDED FOR ADJUSTMENTS IN TURBINE LOCATION

NEWFOUNDLAND AND LABRADOR HYDRO

RODDICKTON MINI-HYDRO DEV.
POWERHOUSE FOUNDATION DETAILS

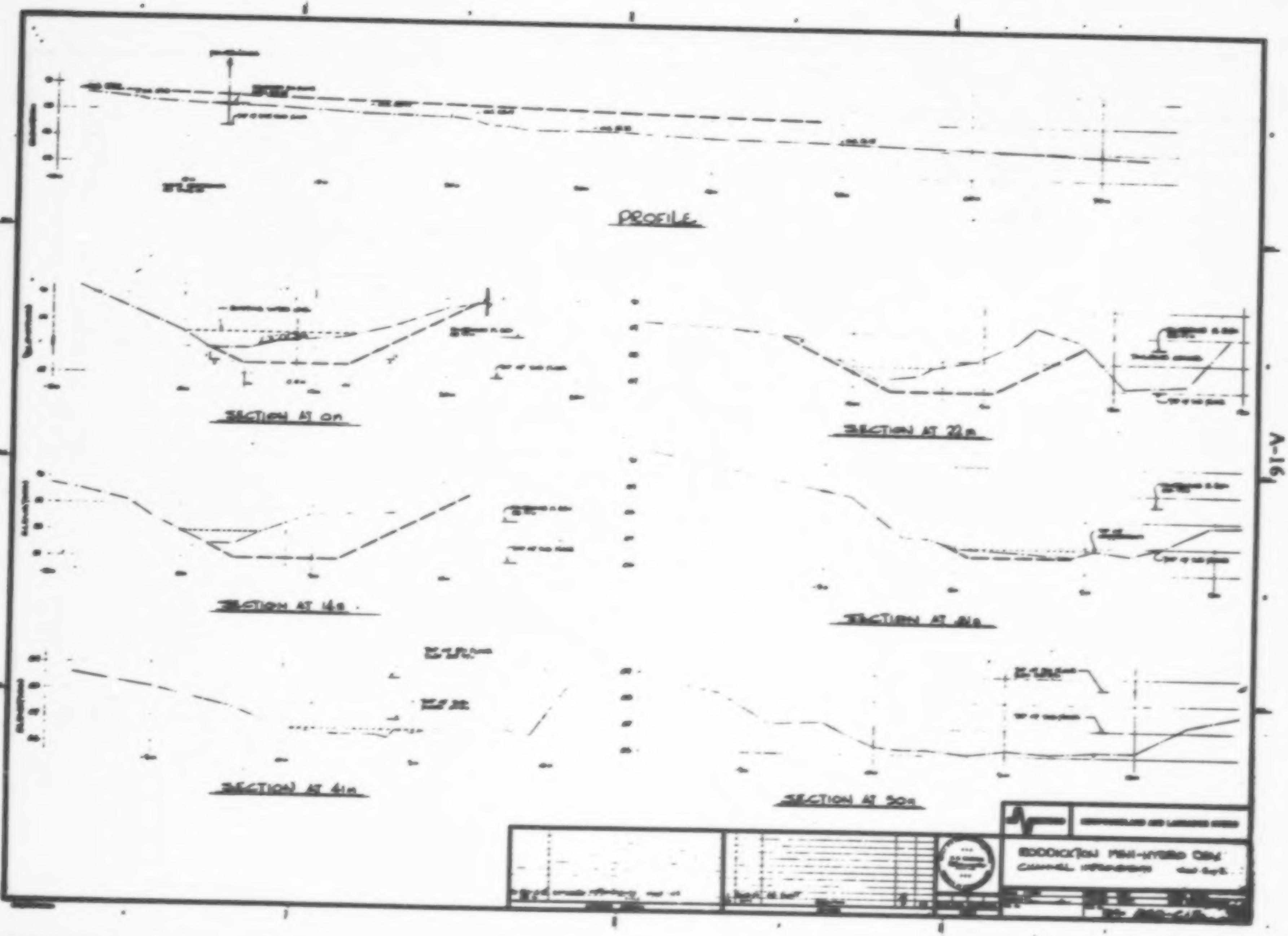


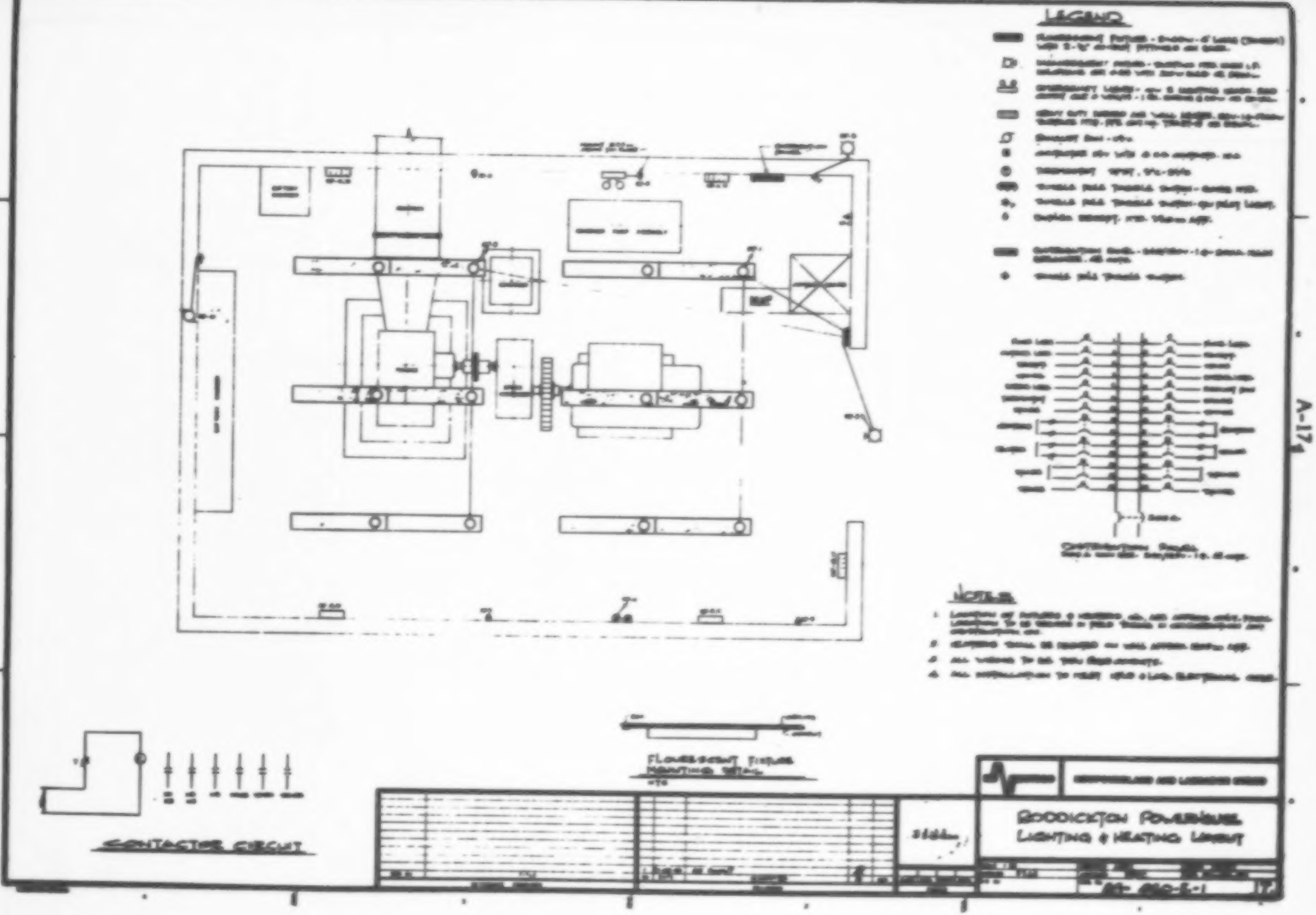
TYPICAL [illegible]

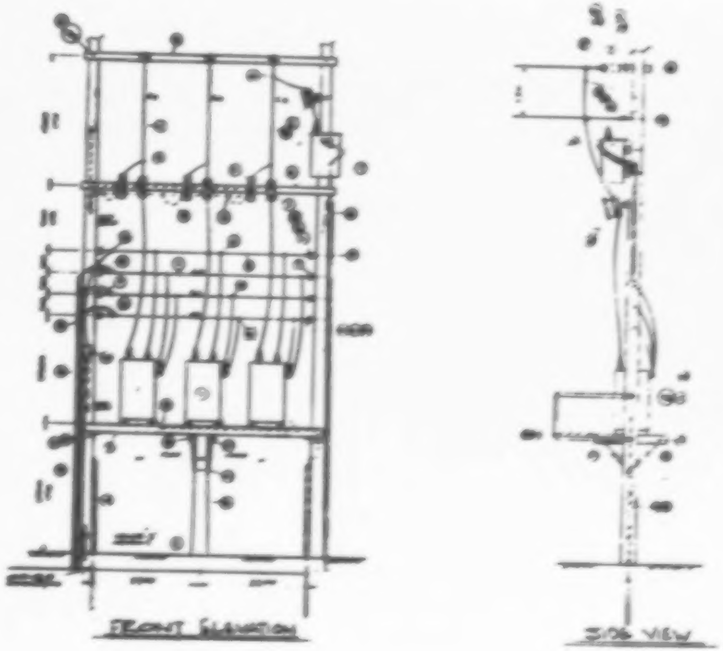
[illegible]

CHANNEL IMPROVEMENTS [illegible]

[illegible] 820-C-13

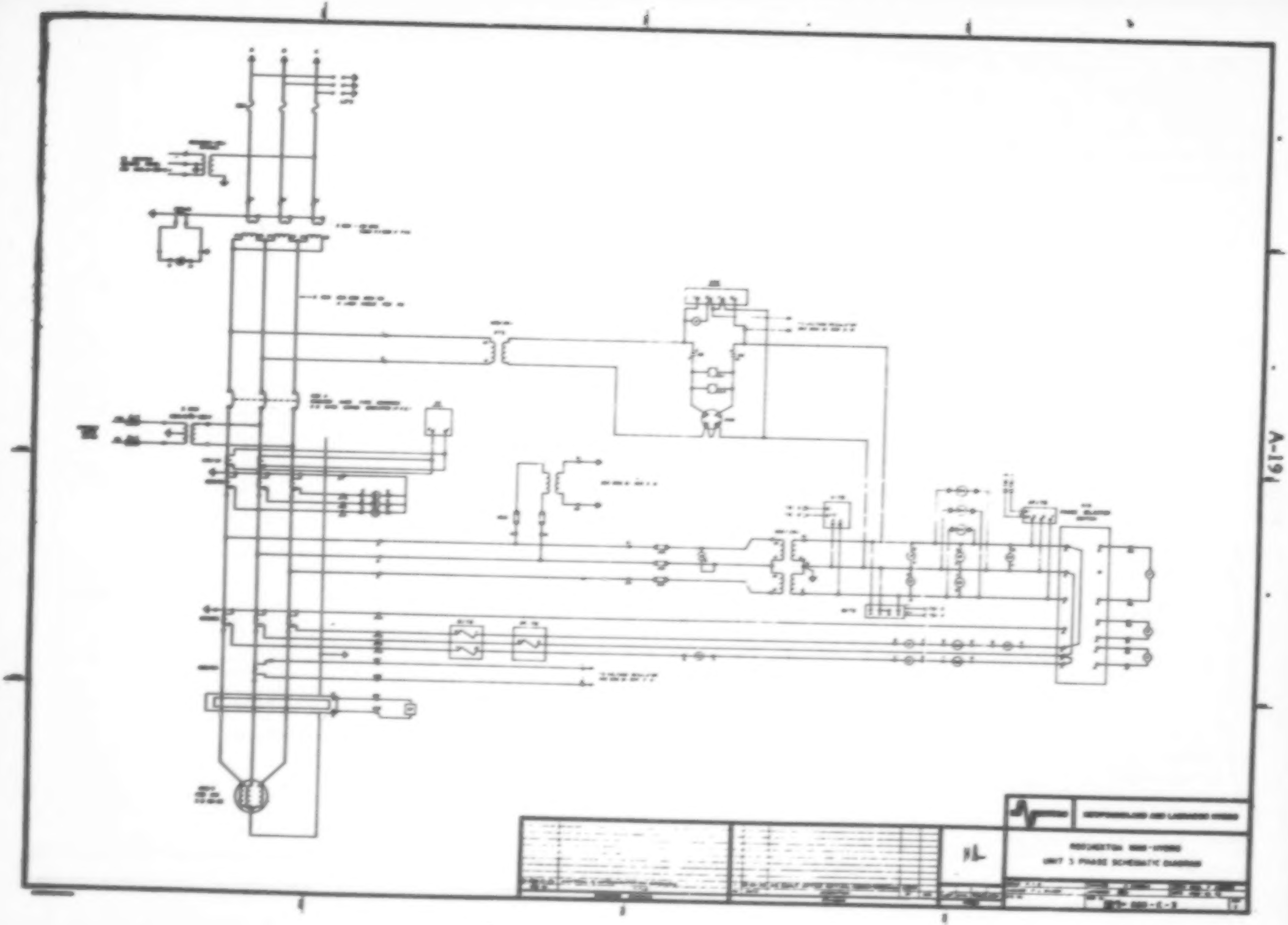

PROFILE
SECTION AT 0m
SECTION AT 22m
SECTION AT 14m
SECTION AT 61m
SECTION AT 41m
SECTION AT 50m
MINI-HYDRO DAM
CHANNEL IMPROVEMENT

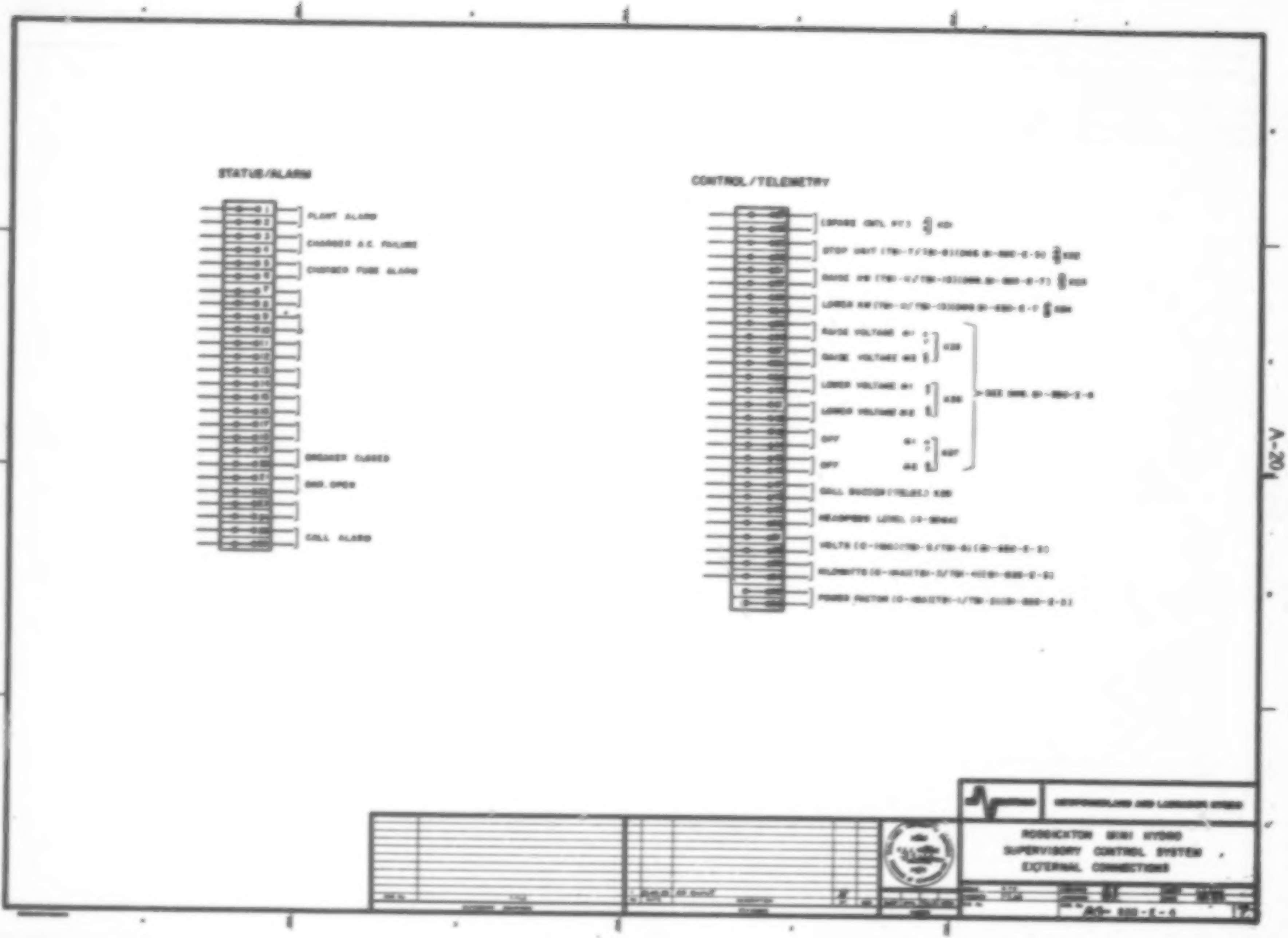

LEGEND
CONTRIBUTION PANEL
NOTES
FLUORESCENT FIXTURE MOUNTING DETAIL
CONTACTOR CIRCUIT
RODDICKTON POWERHOUSE
LIGHTING & HEATING LAYOUT

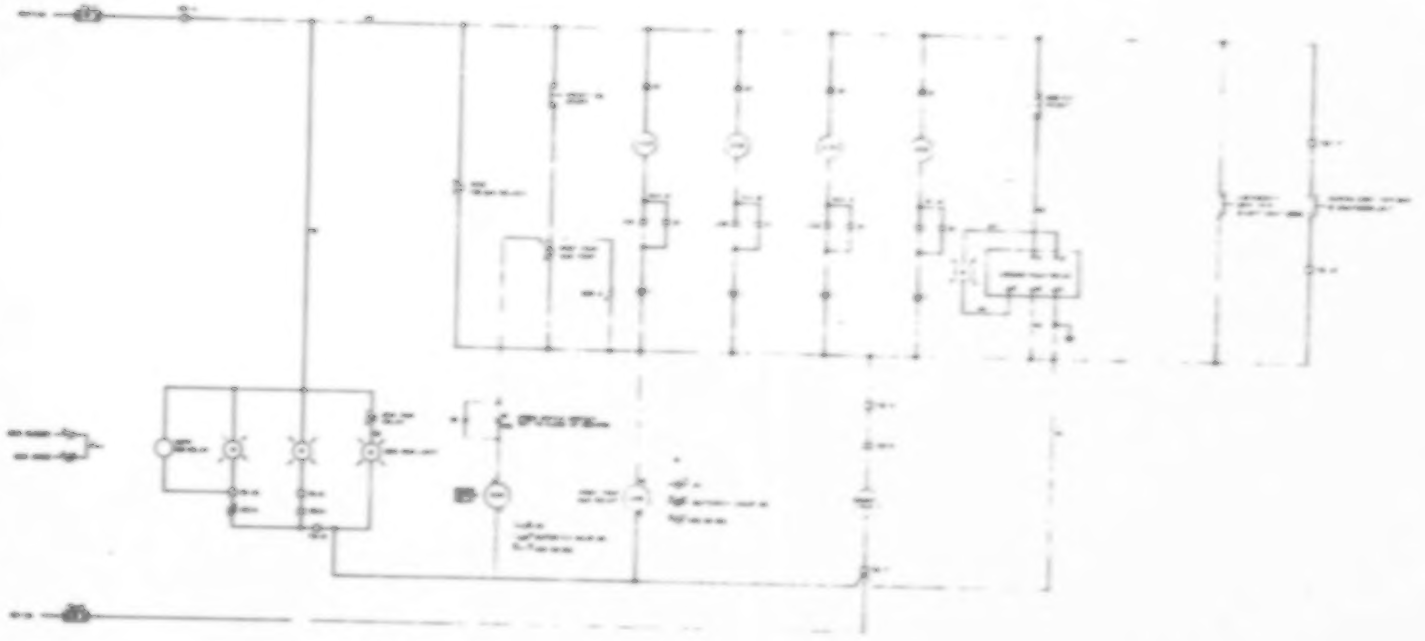

FRONT ELEVATION
SIDE VIEW

NEWFOUNDLAND AND LABRADOR HYDRO

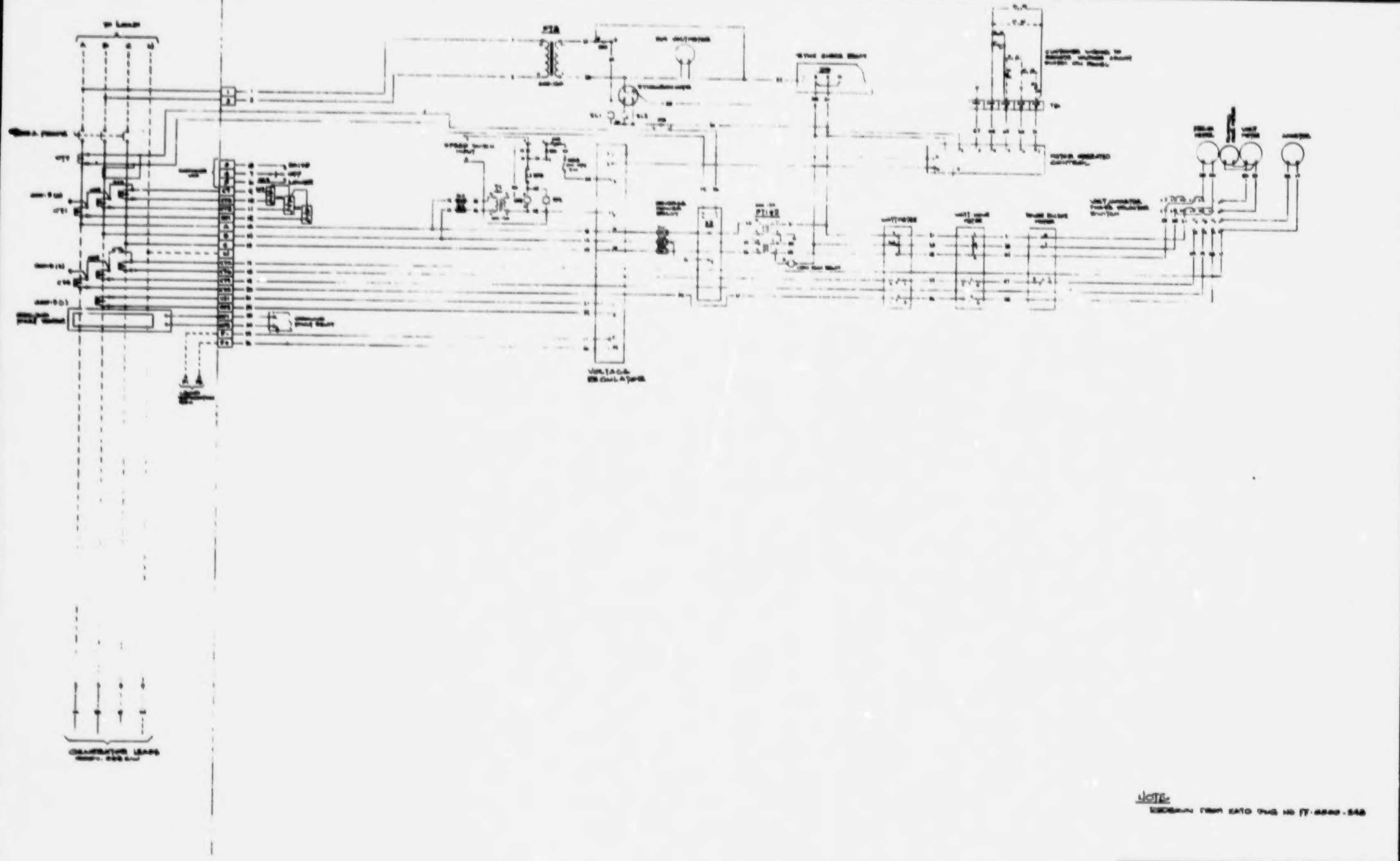
RODDICKTON MINI-HYDRO DEV.
TRANSFORMER BANK AT POWERHOUSE


UNIT 3 PHASE SCHEMATIC DIAGRAM


STATUS/ALARM
PLANT ALARM
CHARGER A.C. FAILURE
CHARGER FUSE ALARM
BREAKER CLOSED
BKR. OPEN
CALL ALARM
CONTROL/TELEMETRY
(SPARE CNTL PT) K01
STOP UNIT (TB-7/TB-8)(DWG R-500-E-5) K02
RAISE KW (TB-9/TB-10)(DWG R-500-E-7) K03
LOWER KW (TB-11/TB-12)(DWG R-500-E-7) K04
RAISE VOLTAGE #1
RAISE VOLTAGE #2
K05
LOWER VOLTAGE #1
LOWER VOLTAGE #2
K06
OFF #1
OFF #2
K07
SEE DWG R-500-E-6
CALL BACKUP (TELE.) K08
HEADPOND LEVEL (4-20mA)
VOLTS (0-1mA)(TB-5/TB-6)(R-500-E-3)
KILOWATTS (0-1mA)(TB-3/TB-4)(R-500-E-3)
POWER FACTOR (0-1mA)(TB-1/TB-2)(R-500-E-3)
NEWFOUNDLAND AND LABRADOR HYDRO
RODDICKTON MINI HYDRO
SUPERVISORY CONTROL SYSTEM
EXTERNAL CONNECTIONS
500-E-4
]



[illegible]
UNIT PROTECTION
SCHEMATIC DIAGRAM

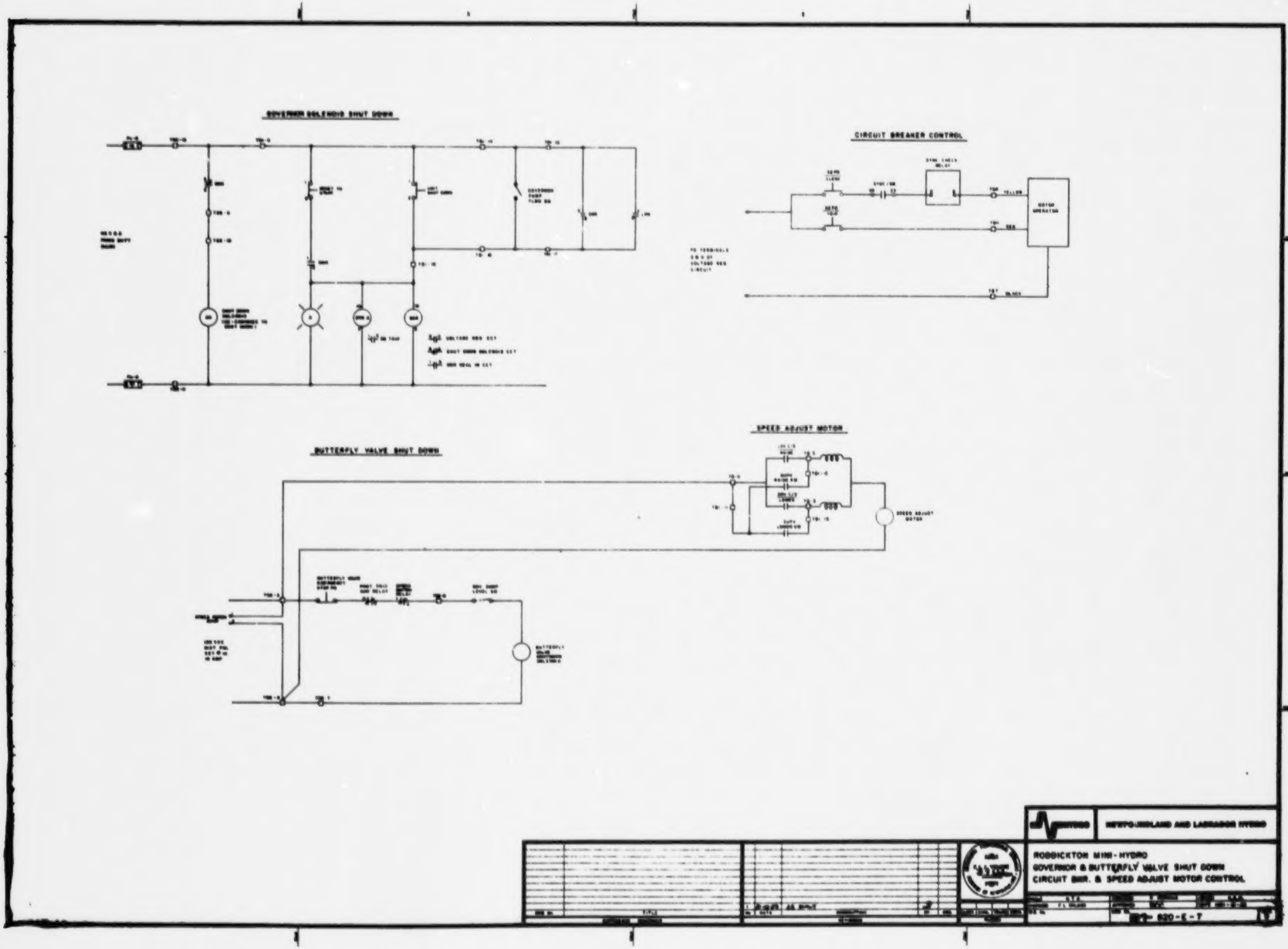

VOLTAGE REGULATOR
GENERATOR LEADS

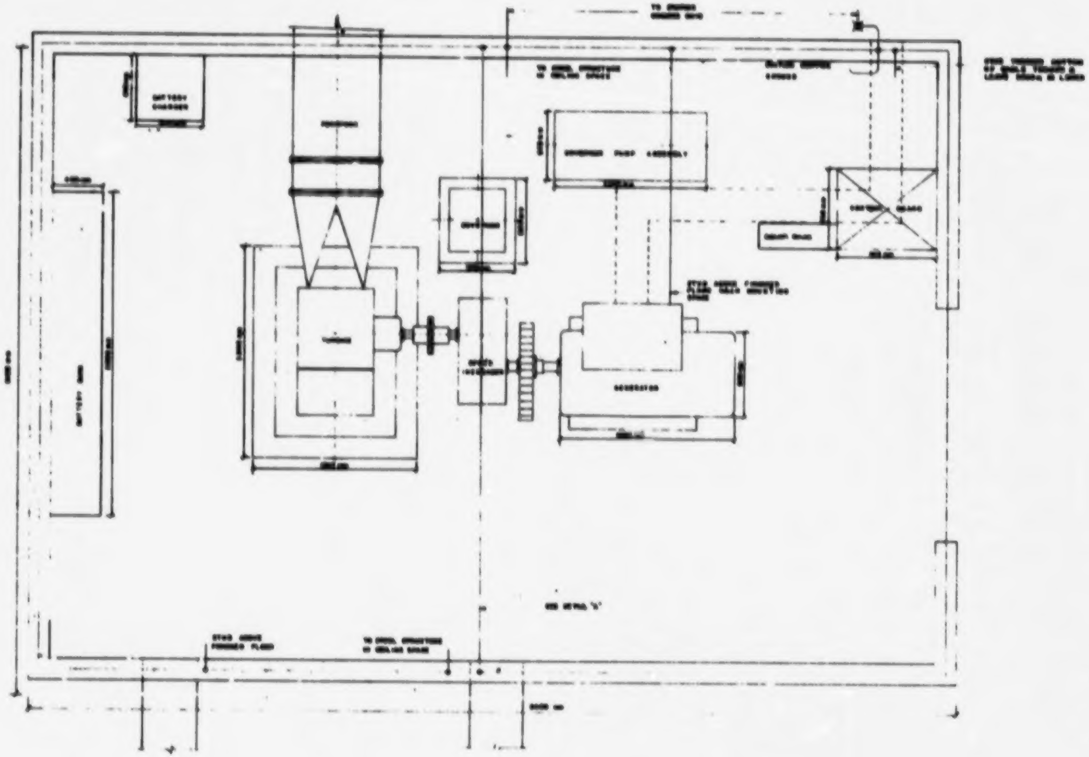
NOTE:
REDRAWN FROM KATO DWG NO [illegible]

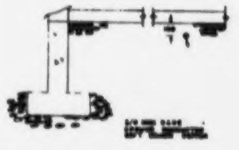
NEWFOUNDLAND AND LABRADOR HYDRO

ROODICKTON MINI-HYDRO DEV.
CONTROL & INSTRUMENTATION
SCHEMATIC & WIRING DETAILS

820-E-6


GOVERNOR SOLENOID SHUT DOWN
CIRCUIT BREAKER CONTROL
SPEED ADJUST MOTOR
BUTTERFLY VALVE SHUT DOWN
MOTOR OPERATOR
YELLOW
RED
BLACK
SPEED ADJUST MOTOR
BUTTERFLY VALVE
NEWFOUNDLAND AND LABRADOR HYDRO
ROBBICKTON MINI-HYDRO
GOVERNOR & BUTTERFLY VALVE SHUT DOWN
CIRCUIT BKR. & SPEED ADJUST MOTOR CONTROL
820-E-7





DETAIL "A"

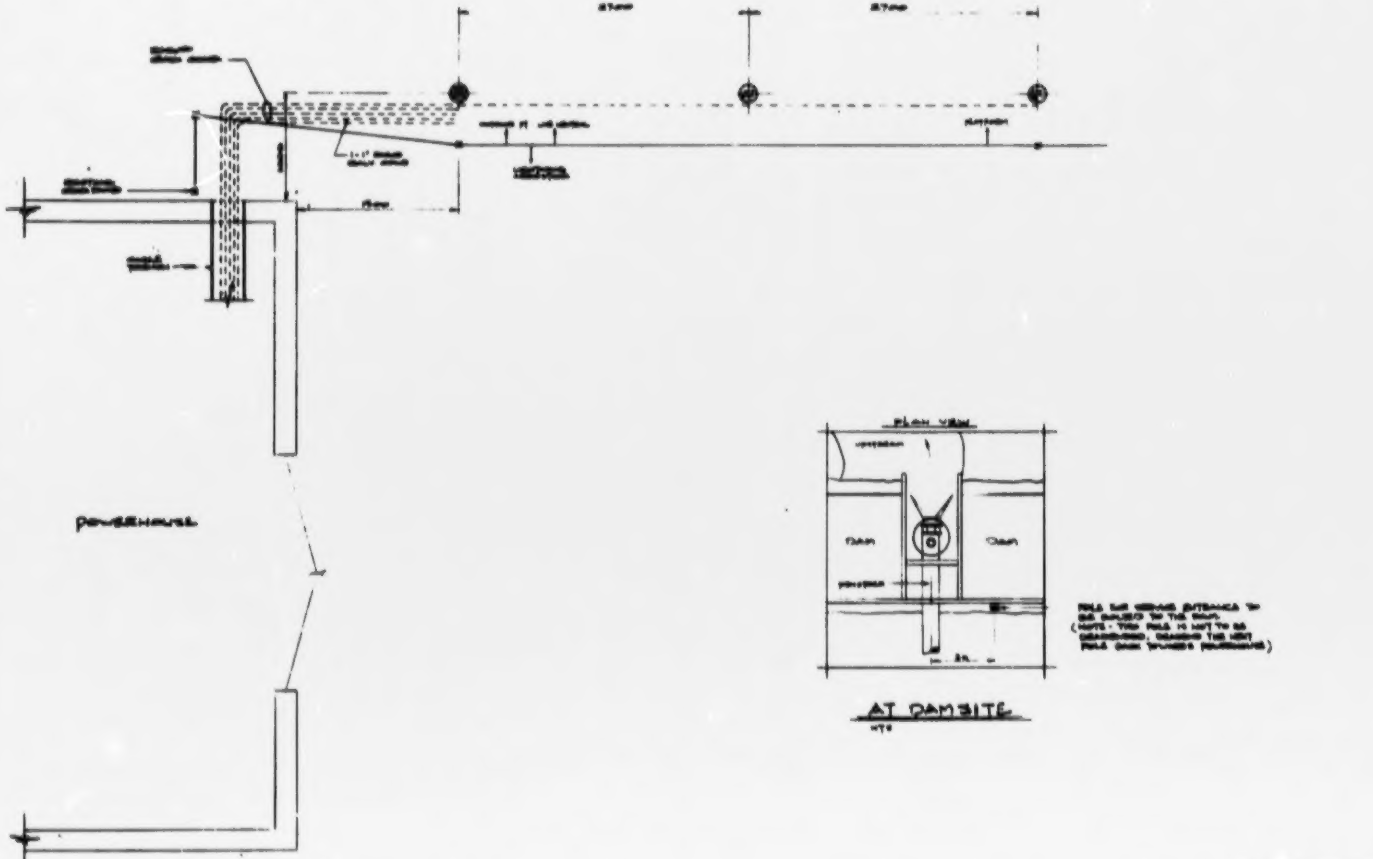
NOTES

1. ALL GROUND CONNECTIONS TO BE [illegible]
2. [illegible] SHALL BE [illegible] 3/0 SOFT DRAWN COPPER & OF LENGTHS AS INDICATED
3. [illegible] INDICATES 20mm Ø x 3000mm LONG COPPER WELD GROUND ROD
4. GROUND WIRE SHALL BE LEFT ABOVE GRADE FOR FUTURE CONNECTION TO GROUND GRID

NEWFOUNDLAND AND LABRADOR HYDRO

RODDICKTON POWERHOUSE
GROUNDING LAYOUT

820-E-8

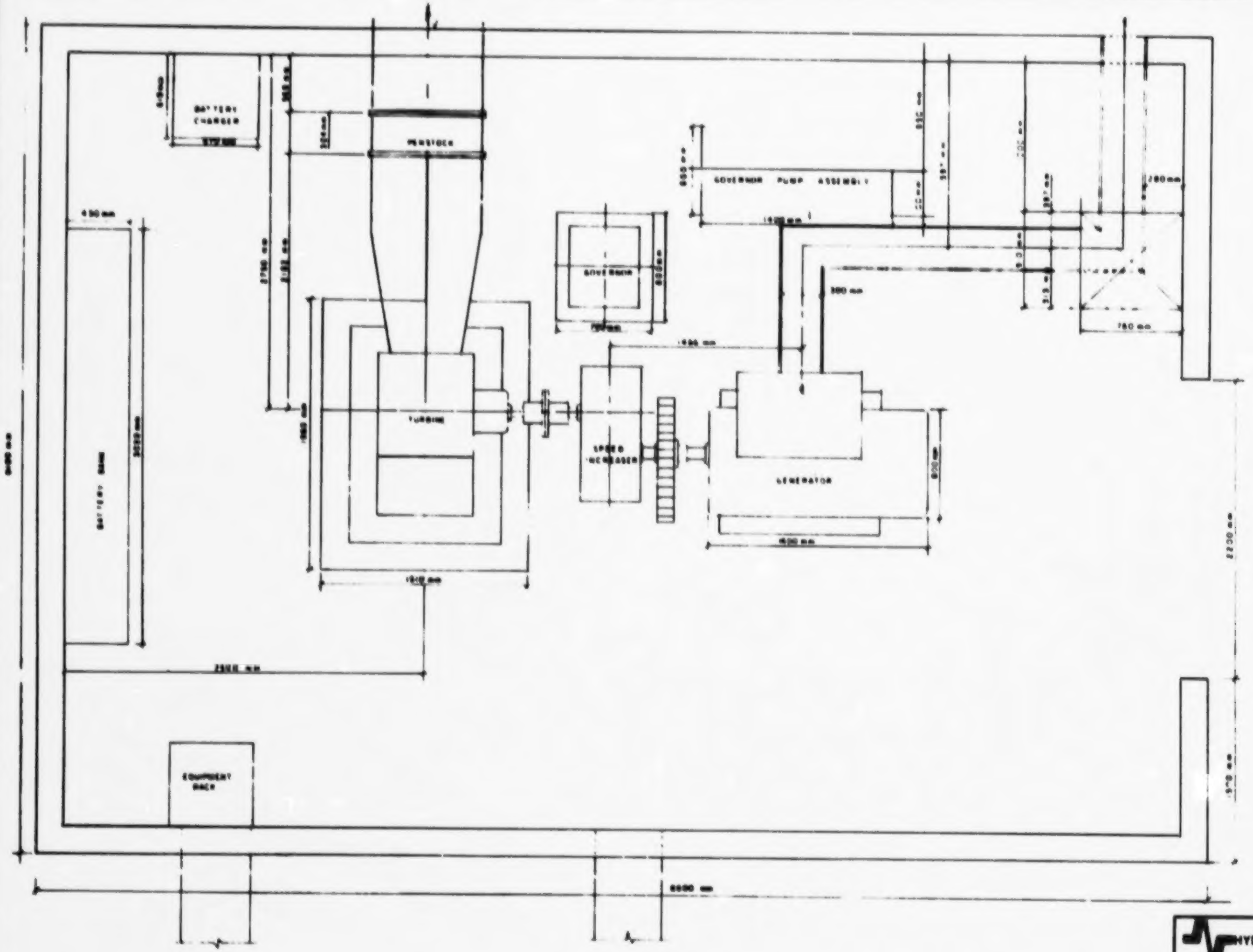

POWERHOUSE
PLAN VIEW
DAM
DAM
AT DAMSITE

NEWFOUNDLAND AND LABRADOR HYDRO

RODDICKTON MINI-HYDRO DEV

MAIN TRANSFORMER BANK +
DAM SITE POLE LOCATION

A1- 820-E-9


BATTERY CHARGER
PENSTOCK
2750 mm
430 mm
BATTERY BANK
TURBINE
1910 mm
2500 mm
GOVERNOR
800mm
SPEED INCREASER
1496 mm
GOVERNOR PUMP ASSEMBLY
1400 mm
380 mm
GENERATOR
920mm
1500 mm
280 mm
760 mm
2230 mm
EQUIPMENT RACK

HYDRO NEWFOUNDLAND AND LABRADOR HYDRO

RODDICKTON POWERHOUSE
EQUIPMENT LAYOUT

SCALE
CHECKED
W.O. NO.
DESIGNED
APPROVED
DWG NO. A1-820-E-10
DRAWN
DATE 80-07-03
3

BILL OF MATERIALS

ITEM No.	QUANTITY	DESCRIPTION	(STOCK) No.	ORDER No.	REMARKS
1	3	OUTDOOR DISTRIBUTION TRANSFORMER, ONAN, 167KVA 65°C RISE, 60 HZ WITH SINGLE HV WINDING, 7200 VOLTS, 95KV BIL, LV WINDING 600 V, TAPS: 2 1/2% F.C. AND 2 1/2% R.C.			33316
2	1	ALUMA FORM VOLTAGE REGULATOR PLATFORM 18' SPAN			33079
3	4	27 KV CUTOUTS 200 AMP FOR CROSSARM MOUNTING	1050173		
4	3	DISTRIBUTION ARRESTORS 9KV CLASS - MCGRAW EDISON TYPE E7	1050007		
5	40M	500 MCM INSULATED CABLE 1KV CLASS	1250732		10 M SPARE
6	3	DEAD END CLAMP FOR 4/0 COPPER C/W EYE HOOK MCGRAW EDISON CAT # 1031C - CLEVIS TYPE			1 SPARE
7	20	SUSPENSION INSULATORS - 10" DISCS, BALL AND SOCKET	2300300		3 SPARE
8	6	D.A. BOLT 5/8" X 22"	1050036		2 SPARE
9	150M	350 MCM RWU-90 X-LINK COOPER CONDUCTOR CABLE 1000 VOLT CLASS		33620	
10	16	SINGLE TAP AND RUN (T-Tap) CONNECTOR, BOLTED TYPE FOF TAP & RUN OF UP TO 500 MCM MCGRAW EDISON CAT # UT081081 (SEE NOTE 1) (Pg 3)			1 SPARE
11	120M	4/0 BARE STRANDED COPPER CONDUCTOR S.D.	1050446		
12	20	SERVIT CONNECTOR BURNDY TYPE KS 28 (# 1 TO 4/0 COPPER)	1050143		6 SPARE
13	1	OUTDOOR CURRENT TRANSFORMER, TYPE JAK-0 RATIO 200/5 CAT # 750 X 33 G 311, C/W SECONDARY TERMINAL CONDUIT BOX CAT # 9699693G			34159
14	7	BOLTED TERMINAL FOR COPPER HYLUG 4 HOLE NEMA PAD (500 MCM CABLE) COPPER MCGRAW EDISON CAT # UT081BOHK PENN UNION CAT# CTL 142 X1 TN			1 SPARE
15	7	DEADEND CLAMP FOR 500 MCM C/W EYE HOOK MCGRAW EDISON CAT # 1034C - CLEVIS TYPE			1 SPARE
16	15	SOCKET EYES 11/16"	1050331		3 SPARE
17	2	WOOD POLE (40')	2300391		
18	3	CROSSARM 4" X 6" X 30' : NOTE 10 FT CAN BE CUT OFF FOR SHIPPING	2300223		
19	1	STATION SERVICE TRANSFORMER 7.2 KV / 120-240 VOLTS 37.5 KVA	1050373		
20	10	BALL LINK EYE BOLTS 5/8" X 14"	1050021		2 SPARE
21	4	GROUND RODS 6 FT. LONG X 5/8" DIA.	1050278		1 SPARE
22	6	PARALLEL GROOVE HOT TAP CONNECTOR FOR 4/0 COPPER (BLACK BURN PGH-49)	1050087		1 SPARE

TITLE

RODDICKTON MINI HYDRO
TRANSFORMER BANK EQUIPMENT

NEWFOUNDLAND AND LABRADOR HYDRO

DRAWN BY:- M. Shafford
DATE:- Oct 15, 1980
CHECKED BY:- M.
APPROVED:- H W Tiem

USE WITH DWG. No. A1-820-E-2
B M No. 820-E-2
SHEET 1 OF 3
REV. 0

BILL OF MATERIALS

ITEM No.	QUANTITY	DESCRIPTION	(STOCK) No.	ORDER No.	REMARKS
23	6	30 AMP CUTOUT FUSE LINKS	105020[illegible]		3 SPARE
24	5M	#1 P.E. COPPER STRANDED CABLE	1050456		
25	5M	4/0 COPPER, INSULATED FOR 1000 VOLTS	1250738		
26	1	WOOD POLE (30 FT)	2300389		
27	2	WOODEN CROSS ARMS 3 3/4" X 4 3/4" X 6'-10"	1050130		
28	5	COMPRESSION DEADENDS FOR 1/0 ARVIDAL - CLEVIS TYPE	1050175		1 SPARE
29	6	BALL LINK EYE NUT 5/8"	1050251		2 SPARE
30	6	MACHINE BOLT - 5/8" X 20"	1050056		
31	6	MACHINE BOLT - 5/8" X 16"	1050054		
32	36	SQUARE WASHERS 2 1/4" X 2 1/4" - 11/16" HOLE	1050442		
33	4	FLAT CROSSARM BRACE (30")	1050436		
34	4	LAG SCREWS 1/2" X 3 1/2"	10502[illegible]		
35	4	CARRIAGE BOLT 3/8" X 4 1/2"	1050027		
36	2	MACHINE BOLT 5/8" X 22"	105005[illegible]		
37	50	STAPLES 1 1/4" WITH 3/8" SPREAD	1050[illegible]00		
38	30	STAPLES 2" FOR PLASTIC MOULDING (11/16 OPENINGS)	1050332		
39	4	MOULDING - PLASTIC TYPE FOR GROUND WIRE	1050250		
40	6	MACHINE BOLT 3/4" X 16"	2300073		
41	6	WASHER SQUARE 3" X 3" WITH 13/16 HOLE	2300486		
42	6	2" X 8" X 12' PLANKING			
43	24	BOLTS FOR PLANKING 3/8" X 3" LONG			
44	4	CABLE BREAKOUTS (HEAT SHRINK) RAYCHEM CAT 9C.B. 3-5 - C/W PLUGS FOR SPARE LUGS			
45	25 PC	4" DIAMETER RIGID CONDUIT (GALVANIZED) 10 FT. LENGTHS			3 SPARE
46	15	4" DIAMETER RIGID CONDUIT 90° ELBOWS - GALVANIZED			

TITLE

RODDICKTON MINI HYDRO
TRANSFORMER BANK EQUIPMENT

NEWFOUNDLAND AND LABRADOR HYDRO

DRAWN BY:- M Shallow
DATE:- Oct 16 1980
CHECKED BY:- M
APPROVED:-

USE WITH DWG. No. A1-820-E-2
B M No. 820-E-2
SHEET 2 OF 3
REV. 0

N-BM-01

BILL OF MATERIALS

ITEM No.	QUANTITY	DESCRIPTION	(STOC.) No.	ORDER No.	REMARKS
47	20	4" DIAMETER RIGID CONDUIT CONNECTOR (GALVANIZED)			
48	5	1" DIAMETER RIGID CONDUIT - 10 FT LENGTHS (GALVANIZED)			
49	4	1" DIAMETER RIGID CONDUIT 90° ELBOWS (GALVANIZED)			
50	5	1" DIAMETER RIGID CONDUIT CONNECTORS GALVANIZED			
51	1	CAP FOR 4" RIGID CONDUIT GALVANIZED			
52	10	BURNDY COPPER HYLUG TYPE XA-L TIN PLATED 2 HOLE PAD CAT # XA312L2			
		(350 MCM CABLE TO ALT LEAD LUGS)			
53	20	BURNDY COPPER HYLUG XA TIN PLATED 1 HOLE PAD CAT # XA31 (350 MCM CABLE			
		TO CIRCUIT BRKR. STUDS OR BUS BARS			
54	2	5 AMP FUSE LINKS STOCK	1050186		
55	1	CONTROL TRANSFORMER 5 KVA 600/240-120 V WESTINGHOUSE CAT # [illegible]		P.O.3444	TO BE MARKED IN TH
					INDOOR SWITCHGEAR
56	1	OVER CURRENT RELAY, DEVICE 51 N IAC 55 .5-2A RANGE		P.O.34159	TO BE MARKED IN TH
					INDOOR SWITCHGEAR
57	1	600 V CIRCUIT BREAKER 600 A, FPE CAT - NF 631600		P.O.32562	TO BE MARKED IN TH
					INDOOR SWITCHGEAR
		NOTE 1. THERE IS A LONG DELIVERY ON THE T-TAP			
		CONNECTOR. (ITEM # 10). EXTRA SPLIT CONNECTORS (1050185) STOCK			
		HAVE BEEN ORDERED FROM STORES AS A TEMPORARY			
		MEASURE AND ARE TO BE REPLACED ASAP			

TITLE

RODDICKTON MINI HYDRO
TRANSFORMER BANK EQUIPMENT

NEWFOUNDLAND AND LABRADOR HYDRO

DRAWN BY:- M Shallow
DATE:- oct 15 1980
CHECKED BY:-
APPROVED:-

USE WITH DWG. No. A1-820-E-2
B M No. 820-E-2
SHEET 3 OF 3
REV. 0

APPENDIX B

SMALL-SCALE HYDRO POTENTIAL IN NEWFOUNDLAND AND LABRADOR AND A GUIDE FOR DESIGN

INTRODUCTION

Many relatively isolated communities in Newfoundland and Labrador depend on a diesel generating plant for their electrical supply. These plants vary in size from about 60 kW to as high as 4000 kW and in total they produce about 60 million kWh per year. The plants are expensive to operate and fuel costs alone ranging from 6 to 14 cents per kWh.

Plans are under way to connect some of these systems to the main transmission grids on the island and in Labrador. However, for some of the communities connection to a grid is virtually out of the question for the foreseeable future. Newfoundland and Labrador Hydro is therefore investigating various methods to reduce the high fuel costs associated with these diesel systems.

Investigations on one of the methods began in 1978 when Newfoundland and Labrador Hydro and the federal Department of Energy, Mines and Resources entered into an agreement to study the potential for small-scale hydro developments close to diesel systems. The study was to be conducted in two stages:

1. An engineering evaluation was to be performed to identify the hydroelectric potential and to recommend a location for the construction of a plant in the 300-1000 kW range.
2. If both parties accepted the recommendation of the engineering evaluation, then construction of the plant would commence.

Total funding for the project was set at \$ 1 200 000, with 90 % coming from the federal government.

This appendix gives an overview of the engineering evaluation leading up to the recommendation of a specific project for construction. This phase of the work was performed by ShawMont Newfoundland Limited*.

SMALL-SCALE HYDRO CONCEPT

Small-scale hydro developments, commonly defined as plants with an installed capacity of less than 10 000 kW, have generally been neglected in recent times, having been overtaken by the growing size of power systems, economies of scale for large developments and the availability of cheap fossil energy. The basic technology is well known (and some would even say old-fashioned) but some fresh thinking is required to assess the potential and bring into operation small-scale hydro developments. There are two distinct problems: the first is how to identify suitable sites and assess their energy potential without the detailed analysis that can be justified only for large-scale hydro. The second is how to conceive, construct and operate a small-scale hydro development in a remote location without incurring prohibitive costs for engineering, mobilization of external resources and control of construction. 'Normal' hydro design and construction practices would result in prohibitive costs in most cases.

The engineering evaluation addressed some of these problems. A simplified technique of hydrological analysis and energy estimation was developed and opportunities identified for simplified construction, installation, control, operation and maintenance that are suitable for relatively isolated locations.

The small-scale hydro developments proposed here are not the 'conventional' hydro electric developments that could completely replace a diesel system. They are designed to serve as 'fuel displacement' and to operate in parallel with the existing diesel system. Their economic benefit is, therefore, solely in the value of the fuel displaced, not as firm system capacity.

METHODOLOGY

To identify the potential of small-scale hydro and to select one site for construction, the evaluation stage proceeded according to the following plan:

1. Identify any of the 51 diesel systems existing in 1978 that probably will be interconnected soon to a main transmission grid. (This eliminated eleven systems, leaving 40 for futher consideration.)
2. Develop a simplified technique to estimate the energy potential of a small stream.
3. Determine the total theoretical potential of all the streams reasonably close to the diesel systems.
4. If more than one potential stream exists close to a particular diesel system, choose the best site overall for that system.
5. Develop preliminary capital cost estimates for these sites and perform an economic analysis of benefits (i.e., value of diesel fuel displaced by hydro generation) versus the plant's capital cost in order to determined economic viability.
6. Develop more detailed estimates for some of the best sites on preliminary field information, and decided on one site for construction.

HYDROLOGY AND ESTIMATION OF ENERGY

In this study it was necessary to evaluate the energy potential of a great many streams widely scattered throughout the province. Because of the number of sites involved, ShawMont developed a method for quickly determining the most suitable installed capacity for each site. The method involves a regional runoff analysis for Newfoundland and Labrador and the derivation of use factors to simplify the conversion of stream flow and system electrical load to potential energy generation.

Readers who wish a detailed description of the techniques developed by ShawMont to derive these use factors, should refer to a paper presented by R.B. Phinney of ShawMont at the Fourth CSCE Atlantic Region Hydrotechnical Conference in St. John's, Newfoundland[5].

SITE INVENTORY

An inventory of potential small-scale hydro sites was produced from a study of 1:50 000 scale topographic mapping of each of the 40 study areas. To ensure that only potentially viable schemes would be included and also to keep the number of sites within reasonable limits, arbitary criteria based on judgment were developed:

1. In an attempt to ensure a continuous year-round flow, the analysis was restricted to sites having drainage areas in excess of 7 km^2 on the Island of Newfoundland and 12 km^2 in Labrador.
2. Because of the accuracy of the mapping a gross head of 4 m was adopted as a minimum.
3. The hydro scheme must be relatively close to the electrical load (i.e., within 8 km of an existing transmission line).
4. To remain within the confines of small-scale hydro, schemes with an installed capacity greater than 10 Mw were not considered.

Of the 40 areas investigated, 28 were found to have at least one potential site for small-scale hydro development satisfying the above criteria. Most of the areas had more than one potential site and in fact the total number of sites for the 28 areas was 83. For each of the sites the theoretical maximum energy potential was determined by using average flow and gross head. These values would not be realized in actual operation since it ignores all spillage and is based on gross head.

It is interesting to note that the total theoretical energy potential identified is about 250 GWh/a far in excess of the total energy requirement for these areas, but on the other hand, many of these sites are expected to be completely uneconomical.

Those areas within which potential sites could not be identified are generally offshore island, sea-bound peninsulas or very flat terrain. Energy consumption in these areas accounts for about 25 % of the total remote diesel generation.

SCREENING

The next step in the appraisal of the 83 initially identified sites was to select a single site for each isolated power system. Because of the many sites to be evaluated, judgment was again used to develop the following criteria for site selection:

1. The energy potential (stream power) of the site should be a reasonable match for the size of the load, since unduly small or large sites would be at a disadvantage.
2. Preference was given to sites with the best blend of physical characteristics (e.g., the shortest distance of access roads and transmission lines, shortest penstock) that gives an indication of costs.
3. Sites that would obviously have been affected adversely by construction and operation were excluded.
4. At this stage, sites obviously having a capital cost in excess of the project budget were also rejected even if they appeared to be attractive.

Application of these criteria did not change the number of areas considered to have hydro potential, which remains at 28, but it did achieve the desired result of reducing the number of sites to one for each area.

An energy and capacity evaluation was now carried out on each site to further refine data for ultimate site selection. The method developed by ShawMont was used for this analysis. It was applied to each of the 28 sites to establish installed capacity and determine useable energy. The total energy potential of the 28 sites was determined to be approximately 19 GWh/a. This large reduction from the value of 250 GWh/a quoted above is caused by (1) reducing the number of sites from 83 to 28; (2) elimination of some of the larger sites, which were either too large relative to the load available or exceeded the budgeted costs; and (3) greater realism being applied than for the theoretical value derived earlier.

The attached Table 5-1 to 5-4 and Figure 5-1, 5-2 are inventory of small scale hydro potential and results of final site screening.

DESIGN, CONSTRUCTION AND OPERATION

Before proceeding further with the selection procedure, some description of the components of small-scale hydro is required. The individual components of a small-scale hydro development are similar to those used in a coventional plant: a diversion dam or weir, an intake, a pressure conduit, and a powerhouse and its enclosed equipment.

Conventional and innovative engineering concepts applicable to each of the principal component features of a typical small-scale hydro development were reviewed with the following fundamental principles in mind:

1. The basic design should be simple.
2. Local materials should be used where possible.
3. Best use should be made of any predominant labor skills generally available in the area or, alternatively, local unskilled labour capable of constructing or installing the facility.

The attached Figure 6-1 to 6-28 are design drawings for the small scale hydro plant

RESERVOIR STORAGE

Dam construction costs and physical site characteristics make it difficult to provide significant storage at the sites identified in this study. In a few cases a small amount of storage is readily available if the level of a natural lake is controlled (seldom by more than ± 1 m). Hence, in general, the hydro developments can be defined as run-of-river and will have considerable spill.

DAMS AND WEIRS (SPILLWAYS)

These are used to block the stream and also usually to provide a deep enough head pond for the power intake. Dams are typically low, perhaps 2 to 4 m in height. Timber crib dams filled with loose rock and faced upstream with timber seem the most suitable for most applications. They will also act as overflow spillways during floods.

INTAKES

A series of conceptual intake designs was prepared for different foundations (rock or earth), flow capacity (0.25 to 4 m^3/s covering most of the potential sites) and using different construction materials (timber, fibreglass or steel). Simple bellmouth intakes made of steel plate and mounted on timber crib framework generally are recommended. Fixed trashracks and manually operated inlet valves would be incorporated. Frazil ice formation is likely at many sites and the risk of occasional intake blockage must be accepted.

WATER PASSAGES

There are two alternative means of conducting water from the intake to the powerhouse, open canals and closed penstocks. Ice cover and frost penetration mean that a functional canal has to be larger (and therefore, more costly) than is appropriate for most potential small-scale hydro developments. Penstocks must generally be protected from freezing by being buried. Qualities and costs for the available penstock materials (steel, fibreglass, polyethylene, concrete, wood stave and ductile iron) were compared, with the result that polyethylene pipe is recommended for most applications and steel pipe for the large plants and more severe service conditions.

TURBINE

The selection of an appropriate turbine is an important factor in small-scale hydro developments. For conventional hydro plants turbine manufacturers normally supply a turbine 'tailor-made' to the specific operating conditions expected. The turbine design is carefully perfected, normally for maximum operating efficiency but generally within a relatively narrow range of unit discharge. For these small-scale hydro developments the turbines will be expected to operate over a wide range of flows and power output.

Custom-made design and manufacture is economically impossible for small turbines and the choice rests with 'off-the-shelf' units. In the last few years, with the increase in fuel prices, interest in small-scale hydro has produced a surge of interest in small turbines and manufacturers now offer competing ranges.

The operating characteristics of the principal types of turbines were reviewed together with their availability in the required size from established suppliers. Three main classes of turbines were considered: impulse turbine (Pelton Wheels), reaction turbines (propellor or Francis) and cross-flow.

The applicability of various types of turbines to the range of installations considered (operating heads range between 4 m and 122 m and capacity from 16 kW to 650 kW) was explored in detail.

Although all three turbine groups can suit some of the potential sites, the cross-flow turbine is applicable over a considerably wider range. Combined with its other features, such as a good efficiency over a wide range of flows, this makes it the best general choice of turbine for this kind of application.

GENERATORS

Induction generators were considered in this study but were not recommended because they generally required a connected synchronous capacity on the system more than five times the rating of the induction generator. With smaller amounts of synchronous capacity connected, satisfactory control of system voltages during connection of the induction generator is not certain.

Synchronous generators are the preferred installation, since they are capable of supplying the system independently.

DESIGN AND CONSTRUCTION

There are two specific recommendations on design and construction procedures that should minimize costs appreciably.

First, the design and construction engineering procedures must be completely modified from those used on large-scale projects. The design should be standardized, using standard components and should not be customized to any great degree. Design work would be limited to the production of sketches of typical structures, the specifying and procurement of required materials and advice throughout the course of the job. Construction engineering assumes an added importance under this arrangement in that it would be the field engineer's responsibility to site the structures, work out any outstanding design details for these structures, provide daily supervision of their construction, and keep records of costs so trends may be recognized early.

Second, because of the size of typical projects (as a general guide, even one of the largest hydro developments envisaged in this study would require no more than 20 to 40 men for construction during the summer season) and the varied type of work involved, hiring directly a small local labour force and renting or, in some instances, purchasing equipment would be preferable. The work should be supervised by a construction superintendent experienced in directing the construction of small-scale works.

CONSTRUCTION COST ESTIMATES

On the basis that the foregoing construction procedures are acceptable, the costs of the developments were established in various levels of detail. Historical data for larger civil works, tempered by judgment and the anticipated effects of the constructed procedures outlined above, were used to arrive at structure costs.

Power generating equipment, the turbine, governor and generator, can be supplied as a total package by some suppliers. For estimating, the total cost of this hydro equipment package was determined. Suppliers were contacted for budget prices, but unfortunately, many suppliers were inundated with enquiries and the response was limited. A formula was derived and published by J.L. Gordon[6] for the cost of this hydro equipment package as a function of net head and rated power output. This formula was adjusted to reflect 1980 Canadian prices, and was used to estimate the cost of the power generating equipment.

OPERATION AND CONTROL

Operation and control measures for the small-scale hydro developments envisaged in the study are determined by the basic concept of replacement of diesel fuel by generation in a run-of-river hydro plant. Thus, the operation of the plant is directed towards production of maximum average annual energy rather than to provision of firm energy as is the concept for most existing hydro installations. Skilled maintenance labour will not normally be readily available. As a consequence of the above, operation and control measures in the development envisaged in the study will be simple and must cater for only the most likely operations.

INVENTORY OF SMALL SCALE HYDRO POTENTIAL

TABLE 5-1
(Sheet 1 of 3)

COMMUNITY	SCHEME	GROSS HEAD, m	DRAINAGE AREA, km^2	AVERAGE FLOW, m^3/s	ENERGY POTENTIAL Gwh/yr	NOMINAL INSTALLED CAPACITY, kw	APPROX. DISTANCE TO EXISTING TRANSMISSION LINE, km	APPROX. DISTANCE TO EXISTING ROAD, km	PENSTOCK LENGTH, m	PENSTOCK/HEAD RATIO
A. WEST COAST - NORTHERN PENINSULA REGION										
Croque	1. Freshwater Creek	4	90	2.97	.85	195	2.0	nil	120	30.0
	2. Croque Brook*	11	10	0.31	0.24	55	1.6	0.8	170	15.4
	3. Le Fond Brook	16	7.4	0.23	0.26	60	1.2	1.2	150	9.4
Flower's Cove	1. Ten Mile Lake	5	270	8.91	3.19	730	4.2	4.2	60	12.0
Grandois	1. Grandois Brook*	12	7.8	0.24	0.20	45	nil	nil	180	15.0
	2. Great Islets Brook*	14	32	0.99	0.98	225	5.6	5.6	275	19.6
	3. Le Fond Brook	16	7.4	0.23	0.26	60	6.0	6.0	150	9.4
Harbour Deep	1. Lower Harbour Deep Brook*	12	32	0.99	0.84	190	0.6	0.6	215	17.9
	2. Harbour Deep Brook West Branch*	37	17	0.53	1.38	315	2.7	2.7	275	7.4
	3. Harbour Deep Brook East Branch*	110	10	0.31	2.41	550	1.4	1.4	640	5.8
	4. Upper Sault Arm Brook*	46	25	.78	2.52	575	1.9	1.9	305	6.6
	5. Lower Sault Arm Brook*	20	25	.78	1.10	250	1.6	1.6	140	7.0
	6. Sault Arm River*	18	186	6.14	7.92	1800	2.8	2.8	105	5.8
	7. North East Arm Brook*	37	21	0.65	1.70	390	5.0	5.0	245	6.6
	8. Soufflets Arm Brook*	34	29	0.90	2.16	490	6.4	6.4	305	9.0
	9. Jacques Cove Brook*	46	15	0.46	1.51	345	4.0	4.0	425	9.2
	10. Southeast Head Brook*	60	17	0.53	2.23	510	6.0	6.0	380	6.3
Roddickton	1. Marble Brook	46	23	0.71	2.32	530	1.4	2.1	485	10.5
	3. Northeast Brook	4	206	6.80	1.95	445	3.7	0.6	105	26.2
	3. Conche Harbour	80	8.0	0.25	1.40	320	2.7	2.9	305	3.8
	4. Hilliers Harbour	107	11	0.34	2.58	590	5.6	5.6	1035	9.7
	5. Mare Cove	140	7.6	0.24	2.33	530	6.6	6.6	520	3.7
St. Anthony	1. Bartletts River	76	18	0.56	3.00	685	5.9	1.3	1650	21.7
	2. Eastern Long Pond-diversion into Parker River	37	17	0.53	1.38	315	7.4	3.2	700	18.9
	3. Eastern Long Pond-diversion into Frenchman's Pond	40	19	0.59	1.66	380	1.3	1.3	820	20.5
	4. Ireland's Brook	35	55	1.82	4.55	1040	7.0	7.0	1130	32.3
B. NOTRE DAME - BONAVISTA REGION										
Westport	1. Wild Cove Brook at Bridge	12	122	3.29	2.82	645	5.8	0.1	90	7.5
	2. Wild Cove Brook above Bridge	7	121	3.27	1.63	370	6.6	0.4	90	12.9
	3. Wild Cove Brook below Bridge	10	125	3.38	2.41	550	4.6	0.5	245	24.5
	4. East Brook	37	16	0.43	1.14	260	2.1	2.1	610	16.5
	5. Purbeck's Brook	14	34	0.92	0.92	210	4.8	5.1	275	19.6

*DENOTES A FICTITIOUS NAME ASSIGNED FOR IDENTIFICATION OF SCHEME

INVENTORY OF SMALL SCALE HYDRO POTENTIAL

TABLE 5-1
(Sheet 2 of 3)

COMMUNITY	SCHEME	GROSS HEAD, m	DRAINAGE AREA, km^2	AVERAGE FLOW, m^3/s	ENERGY POTENTIAL Gwh/yr	NOMINAL INSTALLED CAPACITY, kw	APPROX. DISTANCE TO EXISTING TRANSMISSION LINE, km	APPROX. DISTANCE TO EXISTING ROAD, km	PENSTOCK LENGTH, m	PENSTOCK/ HEAD RATIO
C. SOUTH COAST - BURIN PENINSULA REGION										
Burgeo	1. Seal Brook at Grandy Brook	11	93	4.00	3.14	720	7.2	2.0	95	8.6
	2. Seal Brook at Lower Falls	17	93	4.00	4.85	1100	7.2	1.8	70	4.1
	3. Seal Brook at Middle Falls	9	91	3.91	2.51	575	7.2	1.1	90	10.0
	4. Seal Brook at Upper Falls	16	90	3.87	4.42	1000	7.2	1.0	95	5.9
	5. Kings Harbour Brook	27	112	4.82	9.27	2100	6.9	5.6	425	15.7
	6. Little Seal Brook*	30	23	1.31	2.78	630	8.8	8.8	400	13.3
	7. Little Kings Harbour Brook*	98	8.3	0.47	3.28	750	5.4	4.8	550	5.6
	8. Dry Pond Brook*	76	156	6.71	36.35	8300	12.8	0.8	375	4.9
Francois	1. Northeast Cove	215	7.5	0.43	6.50	1500	6.6	6.6	460	2.1
	2. Cooper Cove	91	12	0.68	4.40	1000	3.2	3.2	730	8.0
Grand Bruit	1. Grand Bruit Falls	9	21	1.20	0.76	175	nil	nil	60	6.7
	2. Roti Brook	6	23	1.31	0.56	125	4.0	4.0	75	12.7
	3. Northwest Brook Pond	5	17	0.97	0.34	80	6.4	6.4	90	18.0
Grey River	1. Nook Brook*	95	21	1.20	8.04	1800	7.8	7.8	490	5.2
La Poile	1. Farmers Brook	6	52	2.24	0.96	220	3.2	4.5	120	20.0
	2. Farmers Brook - east stream	12	10	0.57	0.48	110	3.5	4.7	140	11.7
	3. Farmers Brook - west stream	15	8.8	0.50	0.53	120	5.3	6.4	215	14.3
	4. Broad Cove Brook	65	85	3.66	16.94	3900	5.1	6.4	365	5.6
McCallum	1. Rose Cove	61	7.3	0.42	1.79	410	5.6	5.6	305	5.0
	2. Allans Cove Brook	15	34	1.94	2.06	470	8.5	8.5	120	8.0
Monkstown	1. Monkstown Brook*	38	8.3	0.47	1.27	290	0.3	0.3	185	4.9
	2. Paradise River	6	478	20.55	8.79	2000	7.2	2.7	30	5.0
Petite Forte	1. Northwest Nonsuch Arm	4	20	1.14	0.32	75	2.1	2.1	60	15.0
Petites	1. Northwest Brook	15	52	2.24	2.39	545	7.4	7.4	45	3.0
Rencontre East	1. Northwest Cove	65	8.0	0.46	2.10	480	7.2	7.2	580	8.0
	2. Isle a Glu Pond	49	21	1.20	4.15	950	8.5	8.5	335	6.8
	3. Spout Brook	122	29	1.65	14.26	3250	8.0	8.0	520	4.3
Southeast Bight	1. Little Bona Cove	4	9.1	0.52	0.15	35	2.4	2.4	120	30.0

*DENOTES A FICTITIOUS NAME ASSIGNED FOR IDENTIFICATION OF SCHEME

INVENTORY OF SMALL SCALE HYDRO POTENTIAL

TABLE 5-1
(Sheet 3 of 3)

COMMUNITY	SCHEME	GROSS HEAD, m	DRAINAGE AREA, km^2	AVERAGE FLOW, m^3/s	ENERGY POTENTIAL GWh/yr	NOMINAL INSTALLED CAPACITY, kw	APPROX. DISTANCE TO EXISTING TRANSMISSION LINE, km	APPROX. DISTANCE TO EXISTING ROAD, km	PENSTOCK LENGTH, m	PENSTOCK/ HEAD RATIO
LABRADOR REGION										
Cartwright	1. Cartwirght Brook*	60	15	0.33	1.42	325	3.0	3.5	850	14.2
Charlottetown	1. Northwest Brook*	12	88	2.02	1.76	400	4.3	4.3	150	12.5
	1. Southeast Brook*	5	48	1.06	0.38	85	7.0	7.0	150	30.0
Fox Harbour	1. Port Mornham	5	160	3.68	1.33	300	4.0	5.4	180	36.0
L'Anse-au-Loup	1. L'Anse au Loup River*	14	102	2.35	2.38	540	1.6	1.6	300	21.4
	2. L'Anse au Clair	42	26	0.57	1.72	390	0.7	1.1	490	11.7
	3. Forteau Brook	8	140	3.22	1.86	425	8.0	5.9	60	7.5
	4. Little Pinware River*	15	73	1.68	1.82	415	0.7	0.5	400	26.7
	5. Red Bay Brook	20	35	0.77	1.10	250	nil	0.2	460	23.0
	6. Black Bay Brook	30	53	1.22	2.65	600	8.0	8.0	380	12.7
Makkovik	1. Makkovik Brook at Makkovik Harbour	14	104	2.39	2.42	550	3.8	3.8	580	41.4
	2. Makkovik Brook near Monkey Hill	26	78	1.79	3.38	770	7.2	7.2	395	15.2
Mary's Harbour	1. Mary's River near Mary's Harbour	4	473	10.9	3.15	720	1.9	1.9	120	30.0
	2. Mary's River at Fifty Islands Pond	9	460	10.6	6.89	1575	6.2	6.2	275	30.6
	3. Salt Brook	4	20	0.44	0.13	30	5.1	5.1	107	26.8
Paradise River	1. Paradise Brook*	7	88	2.02	1.03	235	3.4	3.4	200	28.6
	2. Sandwich Bay Brook	5	27	0.59	0.21	50	7.2	7.2	150	30.0
Port Hope Simpson	1. Port Hope Simpson River* at Alexis River	10	122	2.81	2.03	465	3.4	3.4	275	27.5
	2. Port Hope Simpson River* 5 miles upstream	7	106	2.44	1.23	280	7.2	7.2	215	30.7
	3. Notley's Brook	14	48	1.06	1.06	240	8.0	7.2	305	21.8
	4. Bobby's Brook	4	233	5.36	1.55	355	8.6	2.6	120	30.0
Postville	1. English River at Kaipokok Bay	4	510	11.7	3.40	780	7.0	7.0	90	22.5
	2. English River east branch	15	20	0.44	0.47	110	8.5	8.5	215	14.3
Rigolet	1. Rigolet Brook*	27	23	0.51	0.98	225	4.5	4.5	610	22.6

* DENOTES A FICTITIOUS NAME ASSIGNED FOR IDENTIFICATION OF SCHEME

RESULTS OF FINAL SITE SCREENING

Table 5-2

Community	Scheme No. (Ref. Table 5-1)	Gross Head, m	Average Stream Flow, m^3/s	Penstock / Head Ratio
A. NEWFOUNDLAND				
1. Burgeo	2	17	4.00	4.1
2. Croque	1	4	2.97	30.0
3. Flower's Cove	1	5	8.91	12.0
4. Francois	2	91	0.68	8.0
5. Grand Bruit	1	9	1.20	6.7
6. Grandois	1	12	0.24	15.0
7. Grey River	1	95	1.20	5.2
8. Harbour Deep	6	18	6.14	5.8
9. La Poile	4	65	3.66	5.6
10. McCallum	2	15	1.94	8.0
11. Monkstown	1	38	0.47	4.9
12. Petite Forte	1	4	1.14	15.0
13. Petites	1	15	2.24	3.0
14. Rencontre East	3	122	1.65	4.3
15. Roddickton	1	46	0.71	10.5
16. St. Anthony	1	76	0.56	21.7
17. South East Bight	1	4	0.52	30.0
18. Westport	1	12	3.29	7.5
B. LABRADOR				
19. Cartwright	1	60	0.33	14.2
20. Charlottetown	1	12	2.02	12.5
21. Fox Harbour	1	5	3.68	36.0
22. L'Anse-au-Loup	1	14	2.35	21.4
23. Makkovik	2	26	1.79	15.2
24. Mary's Harbour	1	4	10.9	30.0
25. Paradise River	1	7	2.02	28.6
26. Port Hope Simpson	1	10	2.81	27.5
27. Postville	1	4	11.7	22.5
28. Rigolet	1	27	0.51	22.6

PROJECTED MONTHLY AVERAGE LOADS April 1980 - March 1981 TABLE 5-3

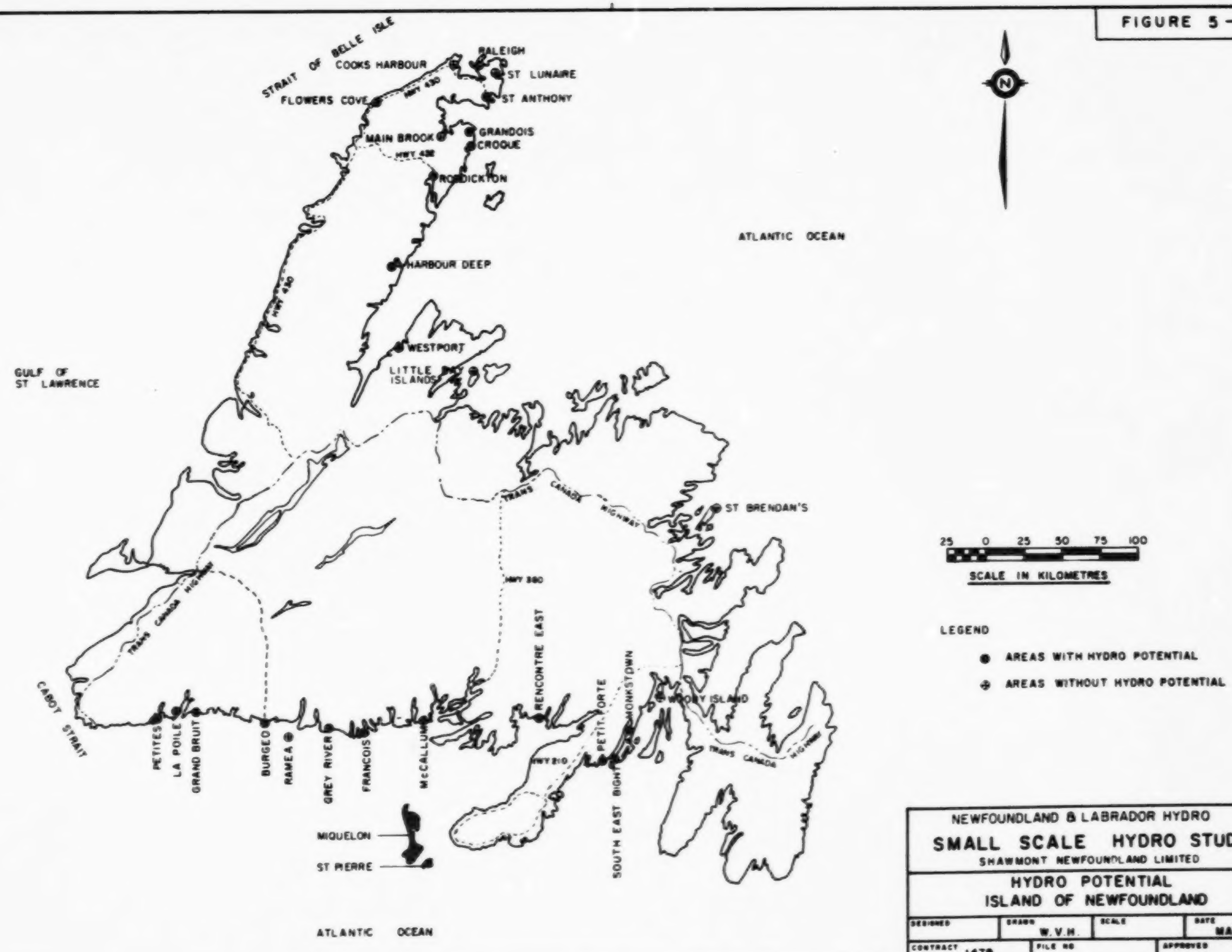
	DIESEL PLANT	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MARCH	AVERAGE
1.	Burgeo	1217	1064	899	1156	924	1096	1169	1250	1332	1360	1360	1373	1183
2.	Cartwright	149	135	132	121	128	149	160	178	203	212	212	194	164
3.	Charlottetown	49	45	29	17	21	33	47	51	63	65	59	57	45
4.	Croque	14	13	8	10	10	15	15	13	16	16	15	17	13
5.	Flowers Cove	1698	1528	1425	1462	1557	1799	1685	1685	2415	1976	1823	2454	1790
6.	Fox Harbour	52	49	39	40	40	55	67	52	75	54	102	60	57
7.	Francois	50	45	85	36	38	40	43	45	57	57	50	69	51
8.	Grand Bruit	22	19	20	23	23	22	22	22	25	23	22	20	22
9.	Grandois	16	16	16	11	13	16	15	15	19	16	17	16	15
10.	Grey River	24	22	29	29	31	31	44	34	36	38	32	34	32
11.	Harbour Deep	82	82	80	64	85	70	86	162	66	98	104	94	89
12.	LaPoile	33	27	29	25	30	35	33	35	43	42	42	42	37
13.	L'Anse-au-Loup	592	510	514	452	347	531	526	631	760	677	671	651	572
14.	Makkovik	61	131	114	135	240	135	240	138	178	236	178	196	165
15.	Mary's Harbour	101	94	67	63	67	82	97	106	127	136	118	118	98
16.	Monkstown	38	28	24	23	35	31	37	40	37	51	52	42	36
17.	McCallum	37	33	31	33	32	36	37	42	50	56	48	47	40
18.	Paradise River	30	28	30	8	28	28	27	30	27	25	37	32	28
19.	Petite Forte	26	17	14	12	12	17	22	26	38	39	38	33	24
20.	Petites	27	26	22	26	25	26	34	31	37	36	44	27	30
21.	Port Hope Simpson	44	51	33	37	33	49	56	86	75	114	133	128	70
22.	Postville	38	36	31	34	32	35	38	47	45	37	42	33	37
23.	Rencontre East	49	38	44	41	41	47	58	41	52	61	56	52	48
24.	Rigolet	45	44	47	37	35	45	32	49	53	52	57	49	45
25.	Roddickton	570	658	671	776	783	666	683	748	667	680	689	859	704
26.	St. Anthony	1673	1714	1805	2039	1930	2009	1994	1950	2096	2083	1997	1950	1937
27.	South East Bight	23	13	10	10	10	12	14	17	23	27	29	30	18
28.	Westport	73	92	89	85	86	121	95	130	129	152	129	134	110

RESULTS OF ENERGY GENERATION STUDY

TABLE 5-4

Community	Installed Capacity, kw	Maximum Turbine Flow, m^3/s	Average Tu-bine Flow, m^3/s	Annual Energy Generated by Hydro, kwh	Capacity Factor	% Total Streamflow Used	% Total Annual Energy Demand Supplied by Hydro
A. NEWFOUNDLAND							
1. Burgeo	650	4.70	2.74	3,316,000	0.58	68	32
2. Croque	17	0.52	0.38	107,000	0.73	13	94
3. Flower's Cove	600	14.75	5.72	2,038,000	0.40	64	13
4. Francois	75	0.10	0.07	429,000	0.70	10	96
5. Grand Bruit	30	0.41	0.28	177,000	0.68	23	92
6. Grandois	16	0.16	0.10	85,000	0.62	41	65
7. Grey River	35	0.05	0.04	247,000	0.73	3	88
8. Harbour Deep	150	1.02	0.59	756,000	0.58	10	97
9. La Poile	50	0.09	0.06	298,000	0.72	2	92
10. McCallum	50	0.41	0.30	326,000	0.74	2	93
11. Monkstown	50	0.16	0.11	300,000	0.69	23	95
12. Petite Forte	35	1.07	0.55	158,000	0.52	48	75
13. Petites	40	0.33	0.23	250,000	0.71	10	95
14. Rencontre East	65	0.07	0.05	408,000	0.67	3	97
15. Roddickton	440	1.18	0.45	1,480,000	0.38	63	24
16. St. Anthony	520	0.84	0.34	1,866,000	0.41	61	11
17. South East Bight	20	0.61	0.30	85,000	0.49	58	54
18. Westport	175	1.79	1.00	858,000	0.56	30	89
B. LABRADOR							
19. Cartwright	130	0.27	0.13	575,000	0.50	39	40
20. Charlottetown	70	0.72	0.37	315,000	0.51	18	80
21. Fox Harbour	60	1.47	0.95	340,000	0.65	26	68
22. L'Anse-Au-Loup	420	3.69	1.40	1,403,000	0.38	60	28
23. Makkovik	200	0.95	0.54	997,000	0.57	30	69
24. Mary's Harbour	130	3.99	2.38	678,000	0.60	22	79
25. Paradise River	35	0.61	0.39	194,000	0.64	19	79
26. Port Hope Simpson	90	1.11	0.59	423,000	0.54	21	69
27. Postville	50	1.54	1.10	314,000	0.72	9	97
28. Rigolet	60	0.27	0.14	280,000	0.54	28	71

FIGURE 5 – I

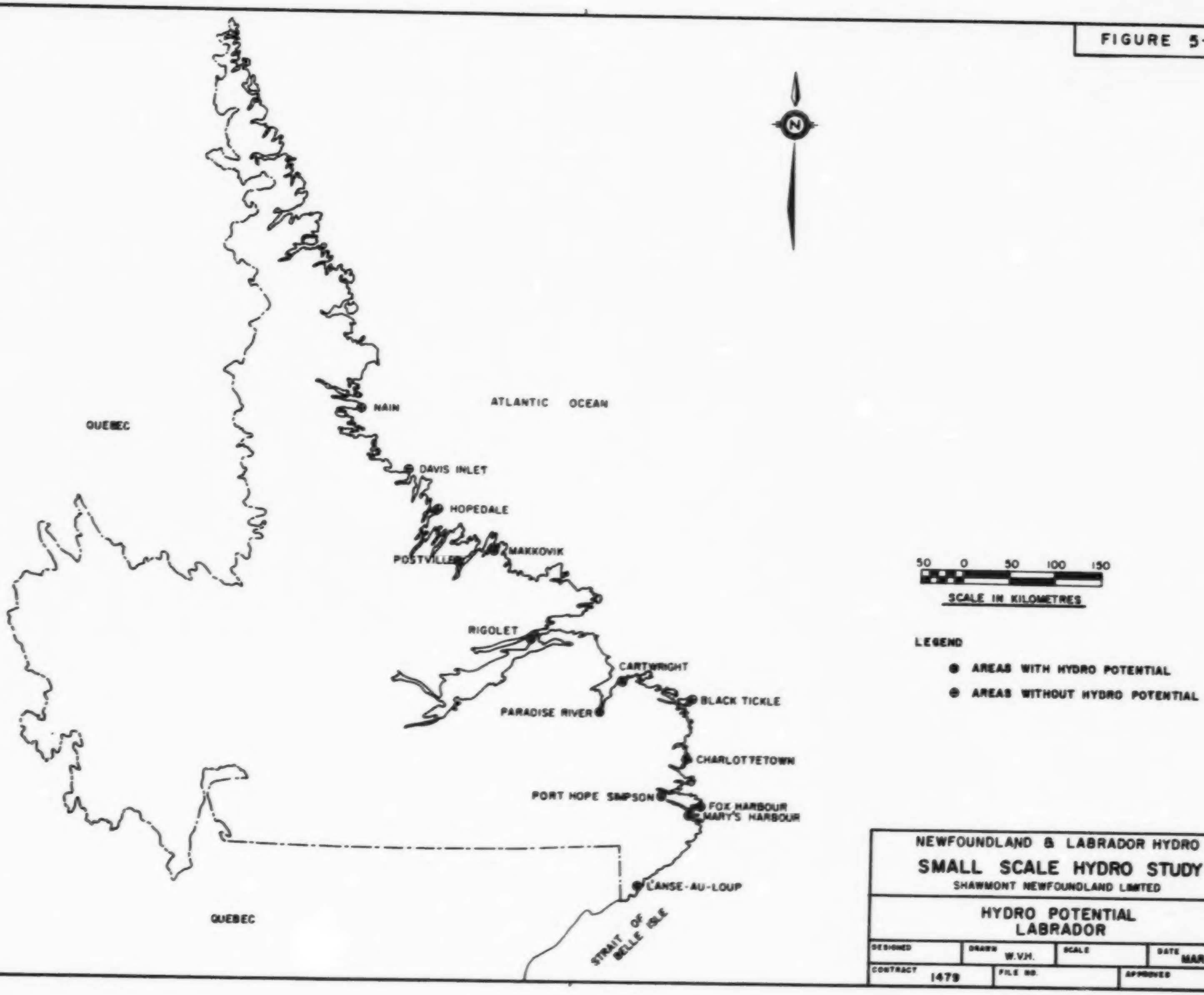

STRAIT OF BELLE ISLE
RALEIGH
ST LUNAIRE
COOKS HARBOUR
ST ANTHONY
FLOWERS COVE
HWY 430
MAIN BROOK
GRANDOIS
CROQUE
HWY 432
ROADDICKTON
HARBOUR DEEP
ATLANTIC OCEAN
WESTPORT
LITTLE BAY ISLANDS
GULF OF ST LAWRENCE
TRANS CANADA HIGHWAY
ST BRENDAN'S
HWY 360
RENCONTRE EAST
MONKSTOWN
PETIT FORTE
SOUTH EAST BIGHT
WOODY ISLAND
HWY 210
CABOT STRAIT
PETITES
LA POILE
GRAND BRUIT
BURGEO
RAMEA
GREY RIVER
FRANCOIS
McCALLUM
MIQUELON
ST PIERRE
ATLANTIC OCEAN
25 0 25 50 75 100
SCALE IN KILOMETRES
LEGEND
● AREAS WITH HYDRO POTENTIAL
⊕ AREAS WITHOUT HYDRO POTENTIAL

NEWFOUNDLAND & LABRADOR HYDRO
SMALL SCALE HYDRO STUDY
SHAWMONT NEWFOUNDLAND LIMITED

HYDRO POTENTIAL
ISLAND OF NEWFOUNDLAND

DESIGNED	DRAWN W.V.H.	SCALE	DATE MAR. 1979
CONTRACT 1479	FILE NO	APPROVED	

FIGURE 5-2


QUEBEC
NAIN
ATLANTIC OCEAN
DAVIS INLET
HOPEDALE
POSTVILLE
MAKKOVIK
RIGOLET
CARTWRIGHT
BLACK TICKLE
PARADISE RIVER
CHARLOTTETOWN
PORT HOPE SIMPSON
FOX HARBOUR
MARY'S HARBOUR
L'ANSE-AU-LOUP
QUEBEC
STRAIT OF BELLE ISLE
N
50 0 50 100 150
SCALE IN KILOMETRES

LEGEND

- ● AREAS WITH HYDRO POTENTIAL
- ● AREAS WITHOUT HYDRO POTENTIAL

NEWFOUNDLAND & LABRADOR HYDRO

SMALL SCALE HYDRO STUDY

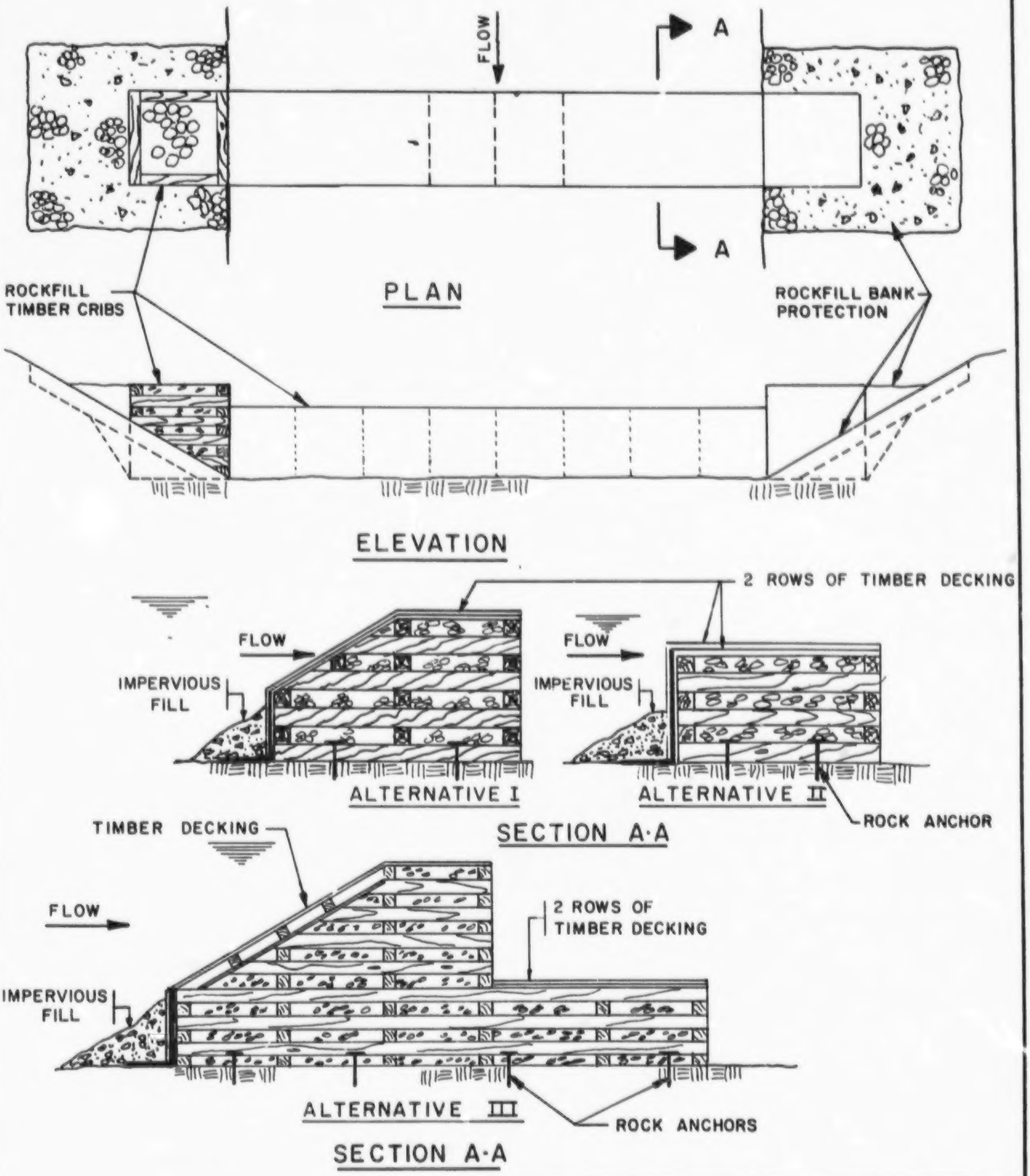
SHAWMONT NEWFOUNDLAND LIMITED

HYDRO POTENTIAL
LABRADOR

DESIGNED	DRAWN W.V.H.	SCALE	DATE MAR. 1979
CONTRACT 1479	FILE NO.		APPROVED

B-179

FIGURE 6-1


FLOW
A
A
ROCKFILL TIMBER CRIBS
PLAN
ROCKFILL BANK PROTECTION
ELEVATION
2 ROWS OF TIMBER DECKING
FLOW
IMPERVIOUS FILL
FLOW
IMPERVIOUS FILL
ALTERNATIVE I
ALTERNATIVE II
ROCK ANCHOR
SECTION A·A
TIMBER DECKING
FLOW
2 ROWS OF TIMBER DECKING
IMPERVIOUS FILL
ALTERNATIVE III
ROCK ANCHORS
SECTION A·A

NEWFOUNDLAND & LABRADOR HYDRO

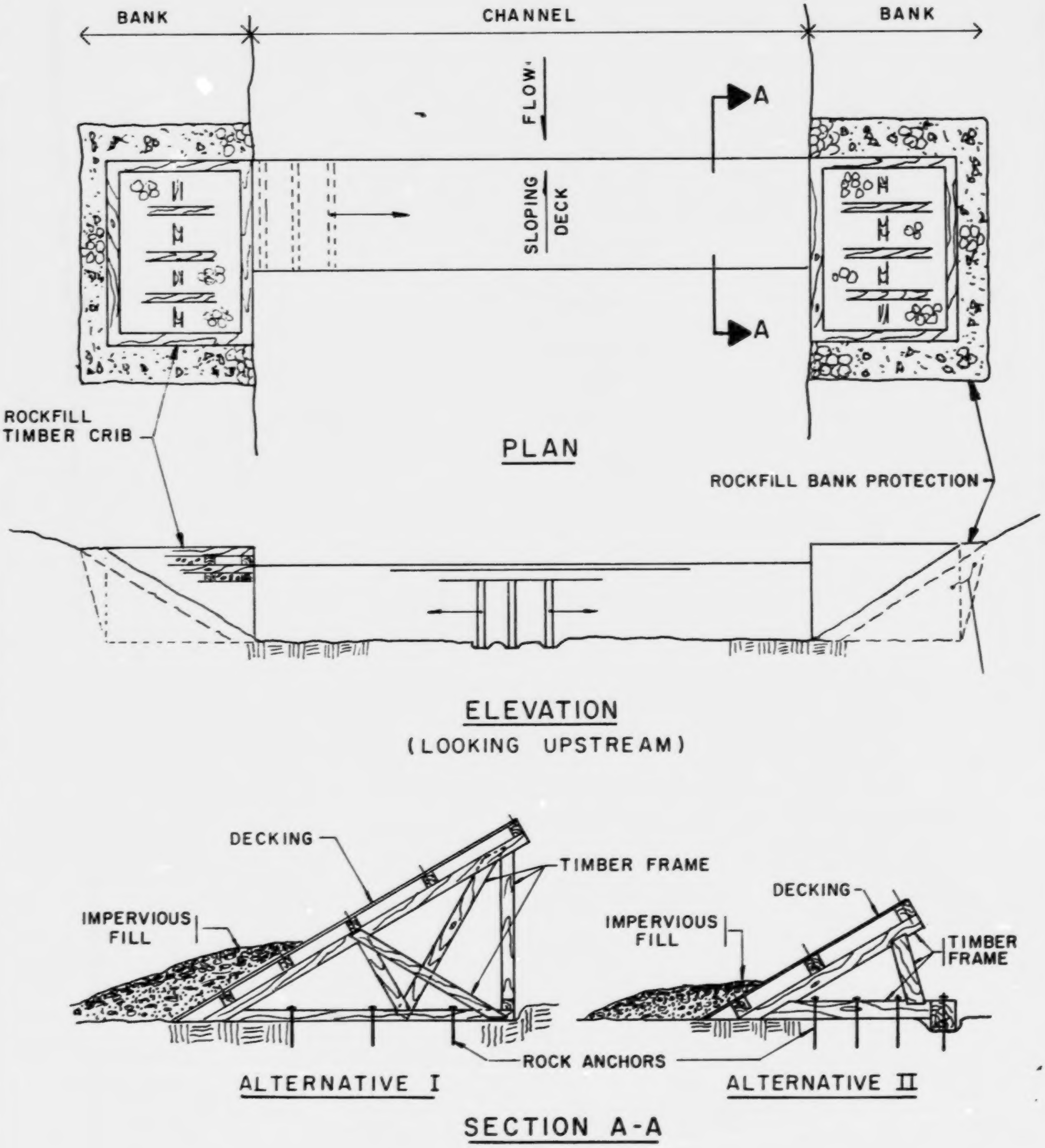
SMALL SCALE HYDRO STUDY

SHAWMONT NEWFOUNDLAND LIMITED

ROCK FILLED TIMBER CRIB DAM
ON LEDGE ROCK FOUNDATION

DESIGNED	DRAWN W. V. H.	SCALE	DATE MAR., 1979
CONTRACT 1479	FILE NO	APPROVED	

FIGURE 6 – 2


BANK
CHANNEL
BANK
FLOW
SLOPING DECK
A
A
ROCKFILL TIMBER CRIB
PLAN
ROCKFILL BANK PROTECTION
ELEVATION
(LOOKING UPSTREAM)
DECKING
TIMBER FRAME
IMPERVIOUS FILL
DECKING
IMPERVIOUS FILL
TIMBER FRAME
ROCK ANCHORS
ALTERNATIVE I
ALTERNATIVE II
SECTION A-A

NEWFOUNDLAND & LABRADOR HYDRO

SMALL SCALE HYDRO STUDY

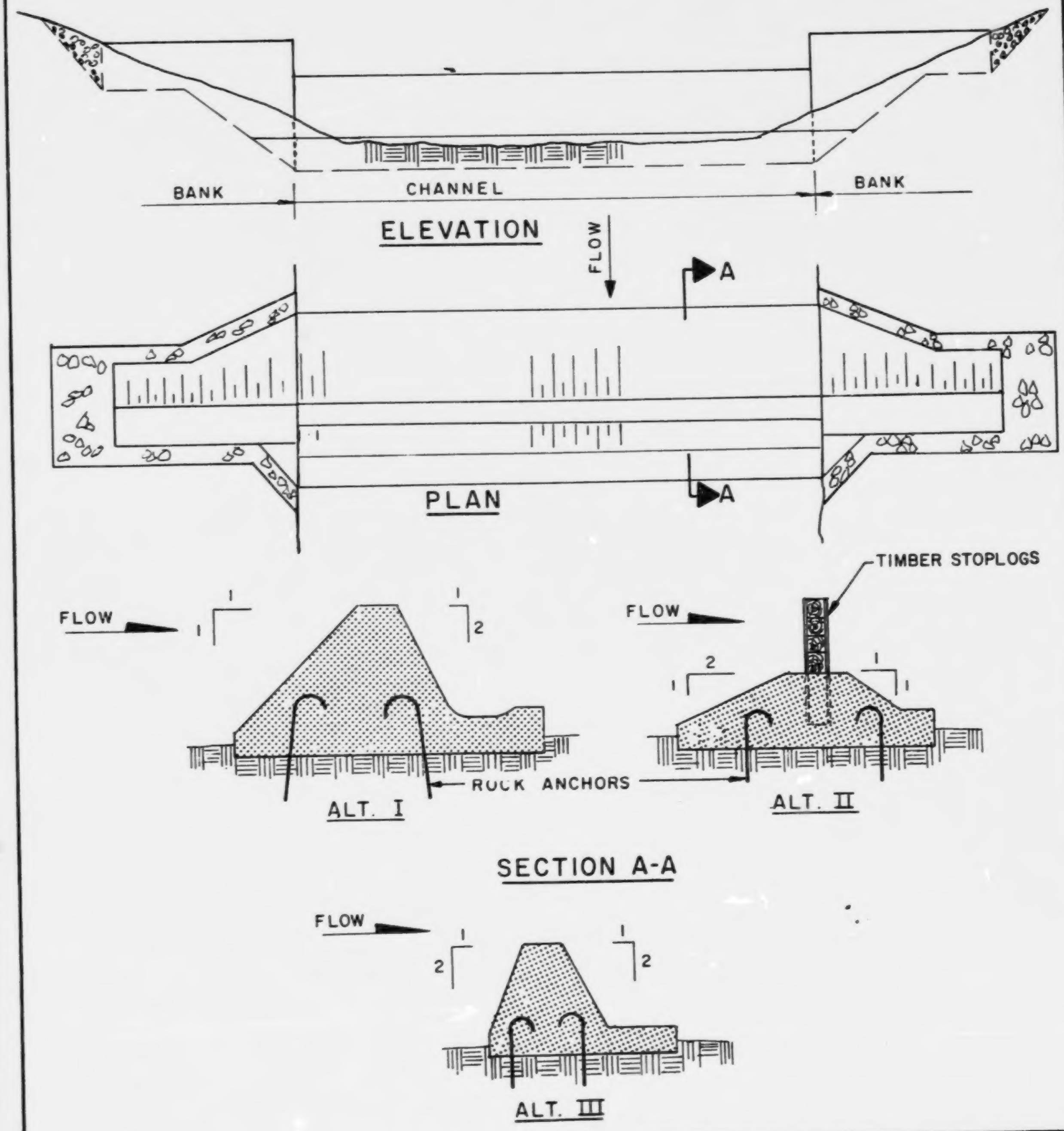
SHAWMONT NEWFOUNDLAND LIMITED

'A' FRAME DAM
ON LEDGE ROCK FOUNDATION

DESIGNED	DRAWN	SCALE	DATE
	W.V.H.		MAR., 1979

CONTRACT	FILE NO	APPROVED
1479		

FIGURE 6-3

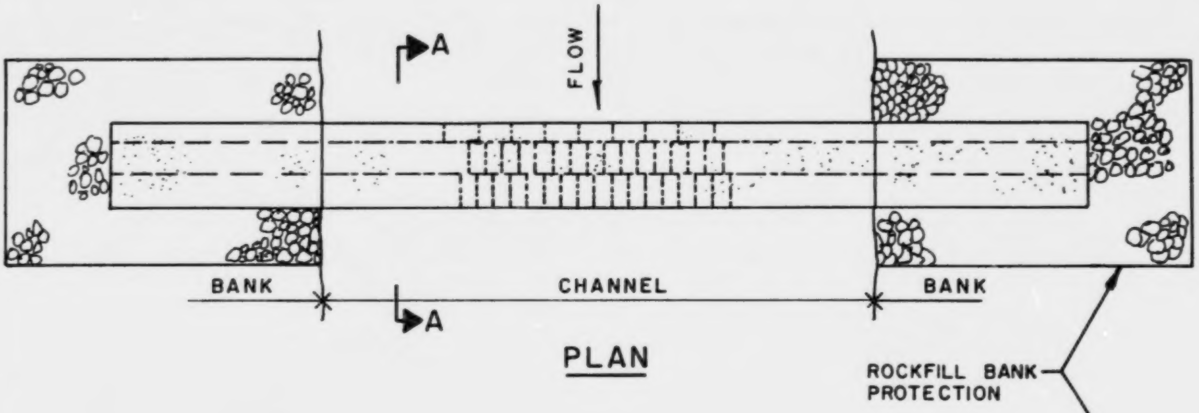

BANK
CHANNEL
BANK
ELEVATION
FLOW
A
A
PLAN
FLOW
1
1
1
2
TIMBER STOPLOGS
FLOW
2
1
1
1
ROCK ANCHORS
ALT. I
ALT. II
SECTION A-A
FLOW
1
2
1
2
ALT. III

NEWFOUNDLAND & LABRADOR HYDRO
SMALL SCALE HYDRO STUDY
SHAWMONT NEWFOUNDLAND LIMITED

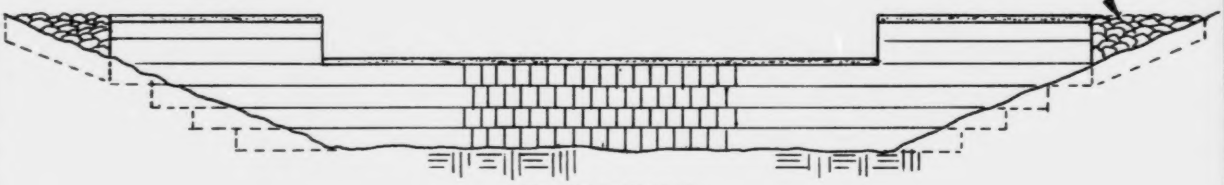
CONCRETE DAM
ON LEDGE ROCK FOUNDATION

DESIGNED	DRAWN W.V.H.	SCALE	DATE MAR.,1979
CONTRACT 1479	FILE NO	APPROVED	

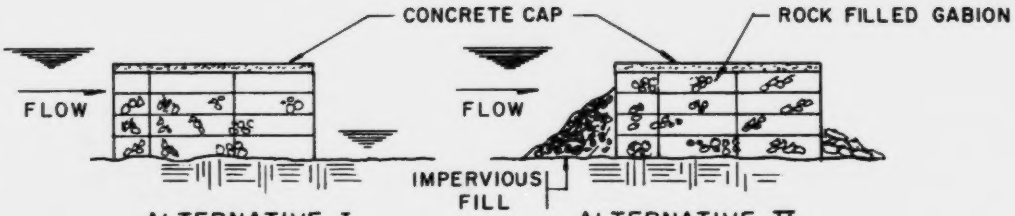
FIGURE 6 – 4


A
FLOW
A
BANK
CHANNEL
BANK
ROCKFILL BANK PROTECTION

PLAN



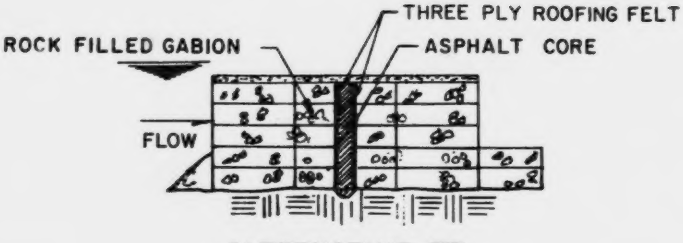
ELEVATION


CONCRETE CAP
ROCK FILLED GABION
FLOW
FLOW
IMPERVIOUS FILL

ALTERNATIVE I

ALTERNATIVE II

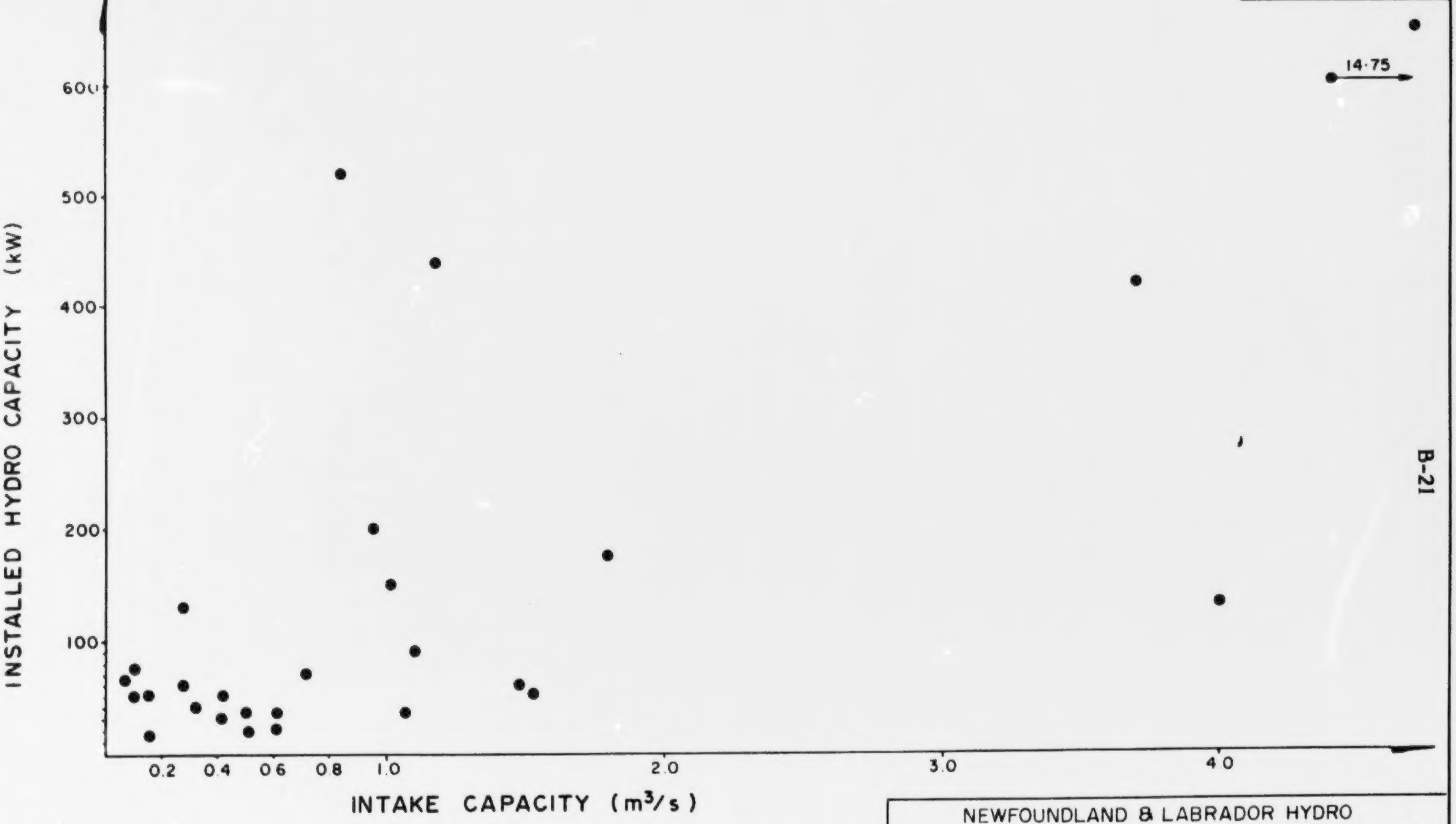
SECTION A-A


THREE PLY ROOFING FELT
ROCK FILLED GABION
ASPHALT CORE
FLOW

ALTERNATIVE III

NEWFOUNDLAND & LABRADOR HYDRO SMALL SCALE HYDRO STUDY SHAWMONT NEWFOUNDLAND LIMITED			
GABION DAM ON LEDGE ROCK FOUNDATION			
DESIGNED	DRAWN W.V.H.	SCALE	DATE MAR., 1979
CONTRACT 1479	FILE NO	APPROVED	

FIGURE 6 – 5



NOTE

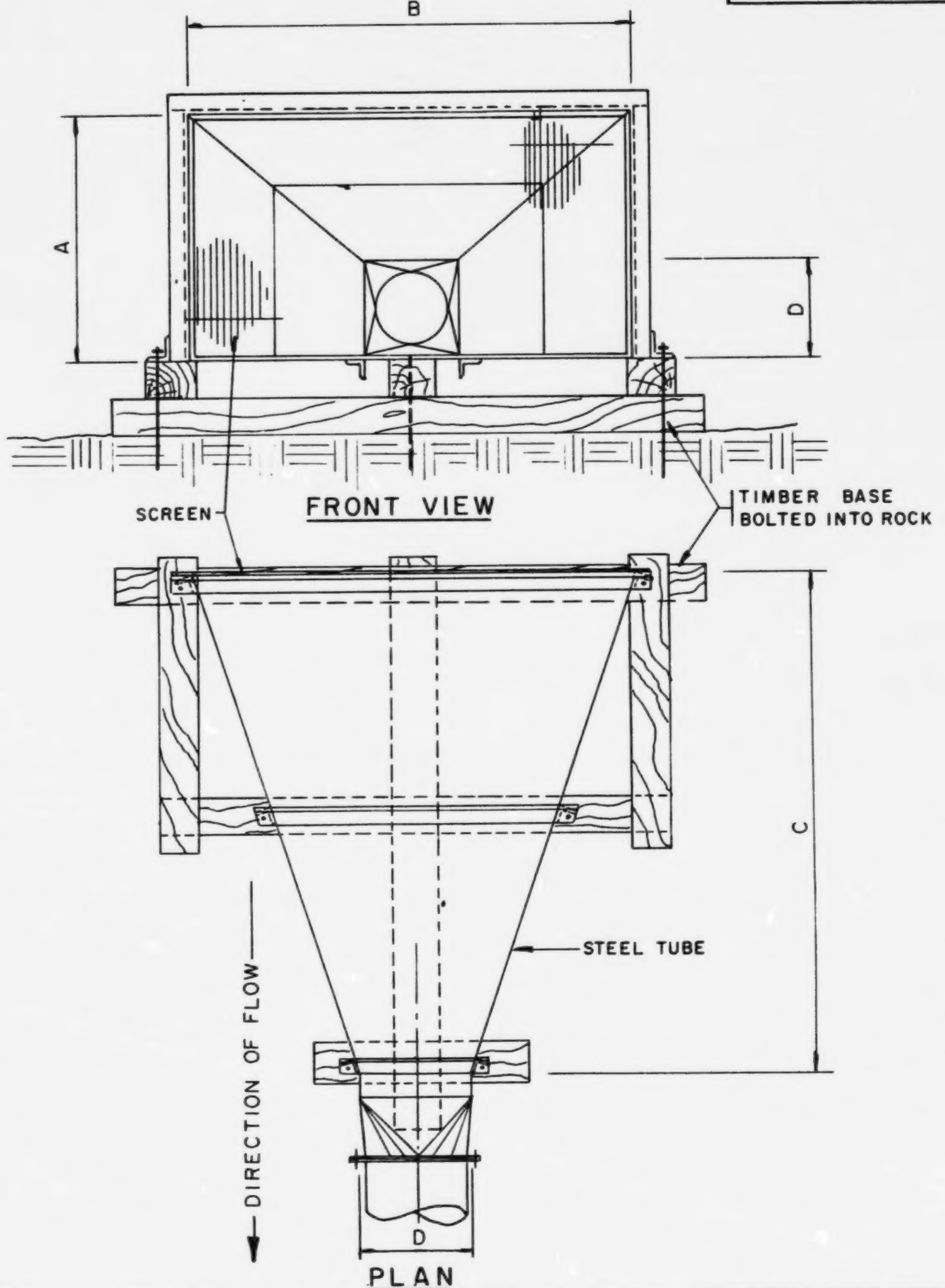
POINTS SHOW MAXIMUM TURBINE FLOWS AND CORRESPONDING INSTALLED CAPACITIES FOR THE 28 FINAL SCHEMES IN TABLES 5-2 AND 5-4

NEWFOUNDLAND & LABRADOR HYDRO
SMALL SCALE HYDRO STUDY
SHAWMONT NEWFOUNDLAND LIMITED

DISTRIBUTION OF INTAKE SIZES

DESIGNED T K	DRAWN RJK	SCALE ~	DATE 79-01-
CONTRACT 1479	FILE NO.	APPROVED	

FIGURE 6-6


B
A
D
SCREEN
FRONT VIEW
TIMBER BASE BOLTED INTO ROCK
C
STEEL TUBE
DIRECTION OF FLOW
D
PLAN

Q INTAKE	A	B	C	D	
m³/sec	cm	cm	cm	cm	(inches)
0.5	120	180	300	30	(12)
1.0	140	300	300	61	(24)
1.5	150	430	300	76	(30)

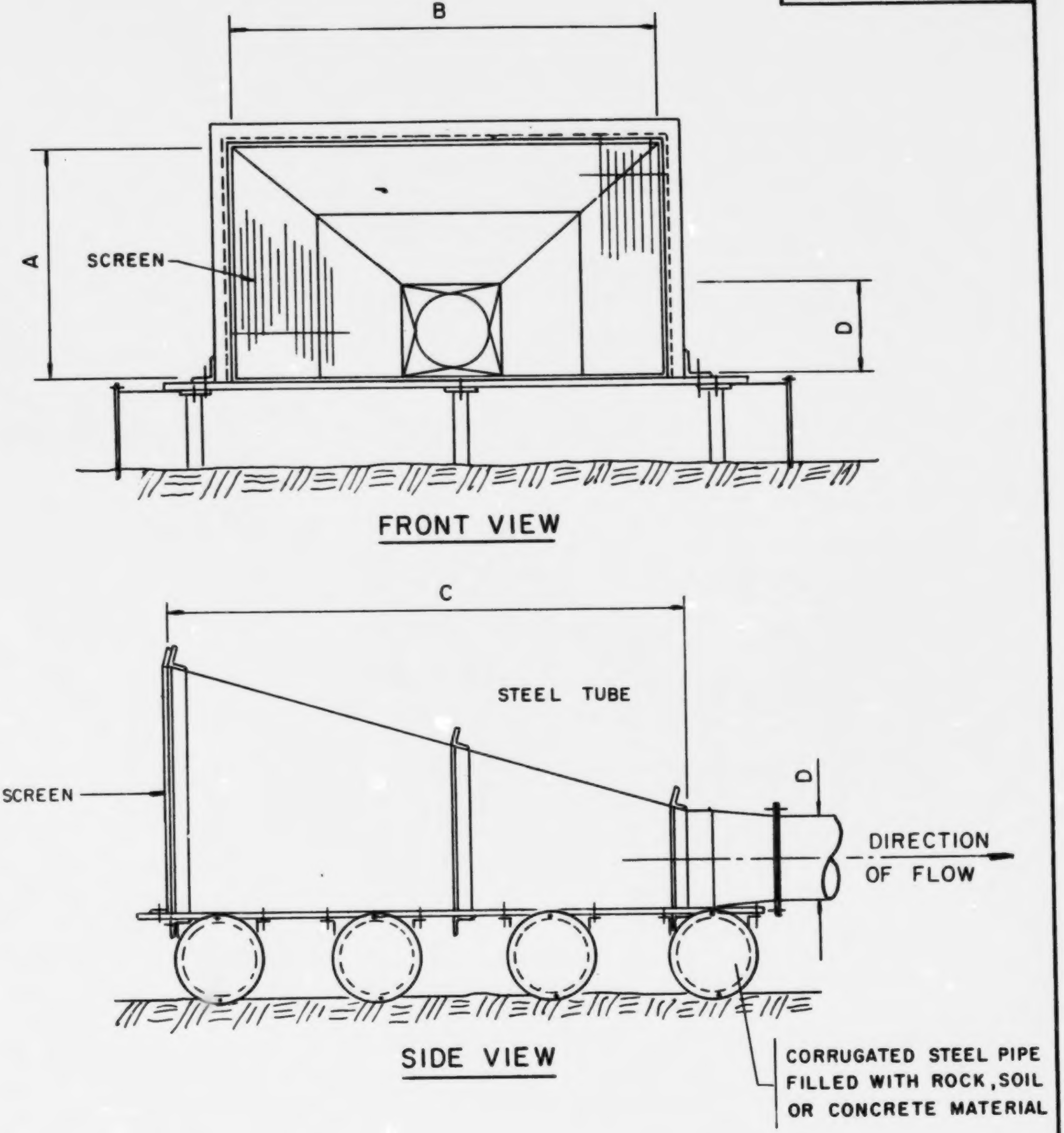
STANDARD DIMENSIONS OF INTAKES

NEWFOUNDLAND & LABRADOR HYDRO
SMALL SCALE HYDRO STUDY
SHAWMONT NEWFOUNDLAND LIMITED

STEEL TUBE INTAKE STRUCTURE
ROCK FOUNDATION

DESIGNED T.K.	DRAWN RJK	SCALE ~	DATE 79-01-
CONTRACT 1479	FILE NO		APPROVED

FIGURE 6 – 7


B
A
SCREEN
D
FRONT VIEW
C
STEEL TUBE
SCREEN
D
DIRECTION
OF FLOW
SIDE VIEW
CORRUGATED STEEL PIPE
FILLED WITH ROCK, SOIL
OR CONCRETE MATERIAL

NOTE:

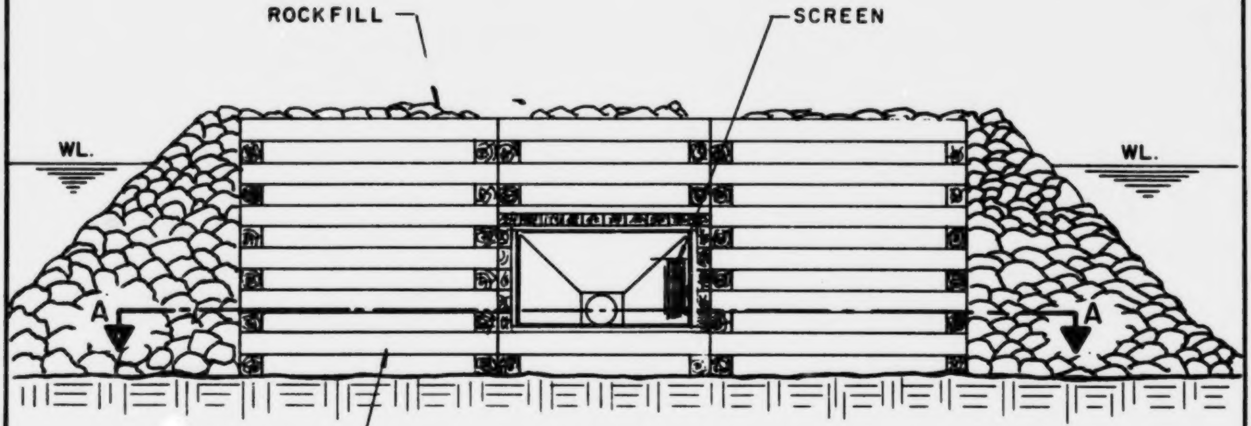
STANDARD DIMENSIONS SHOWN
SEE FIGURE

NEWFOUNDLAND & LABRADOR HYDRO
SMALL SCALE HYDRO STUDY
SHAWMONT NEWFOUNDLAND LIMITED

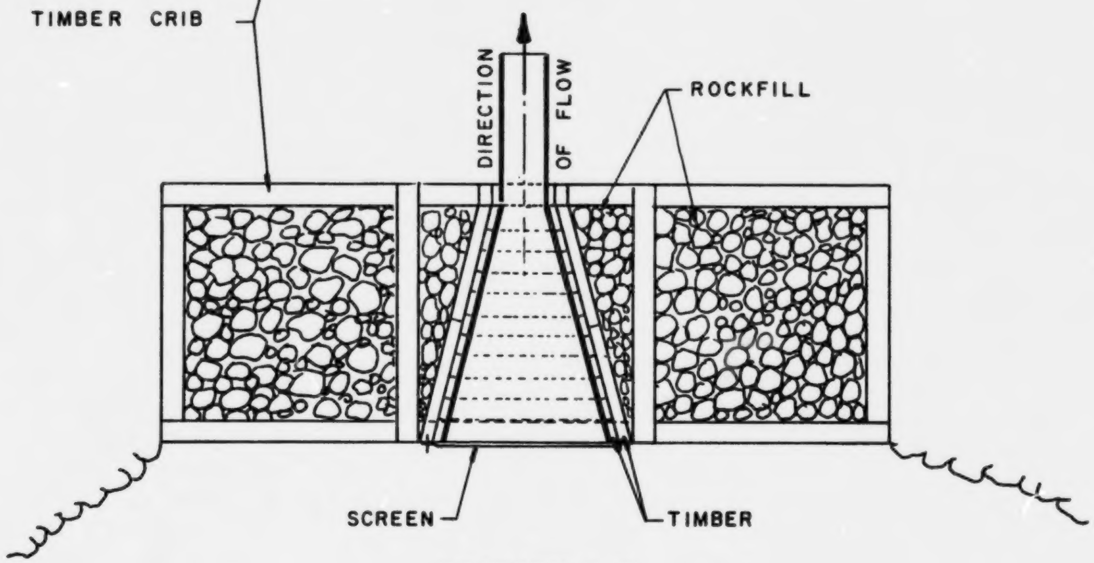
STEEL TUBE INTAKE STRUCTURE
SOIL FOUNDATION

DESIGNED T.K	DRAWN RJK	SCALE ~	DATE 79-01-
CONTRACT 1479	FILE NO		APPROVED

FIGURE 6-8


ROCKFILL
SCREEN
WL.
WL.
A
A

ELEVATION


TIMBER CRIB
DIRECTION OF FLOW
ROCKFILL
SCREEN
TIMBER

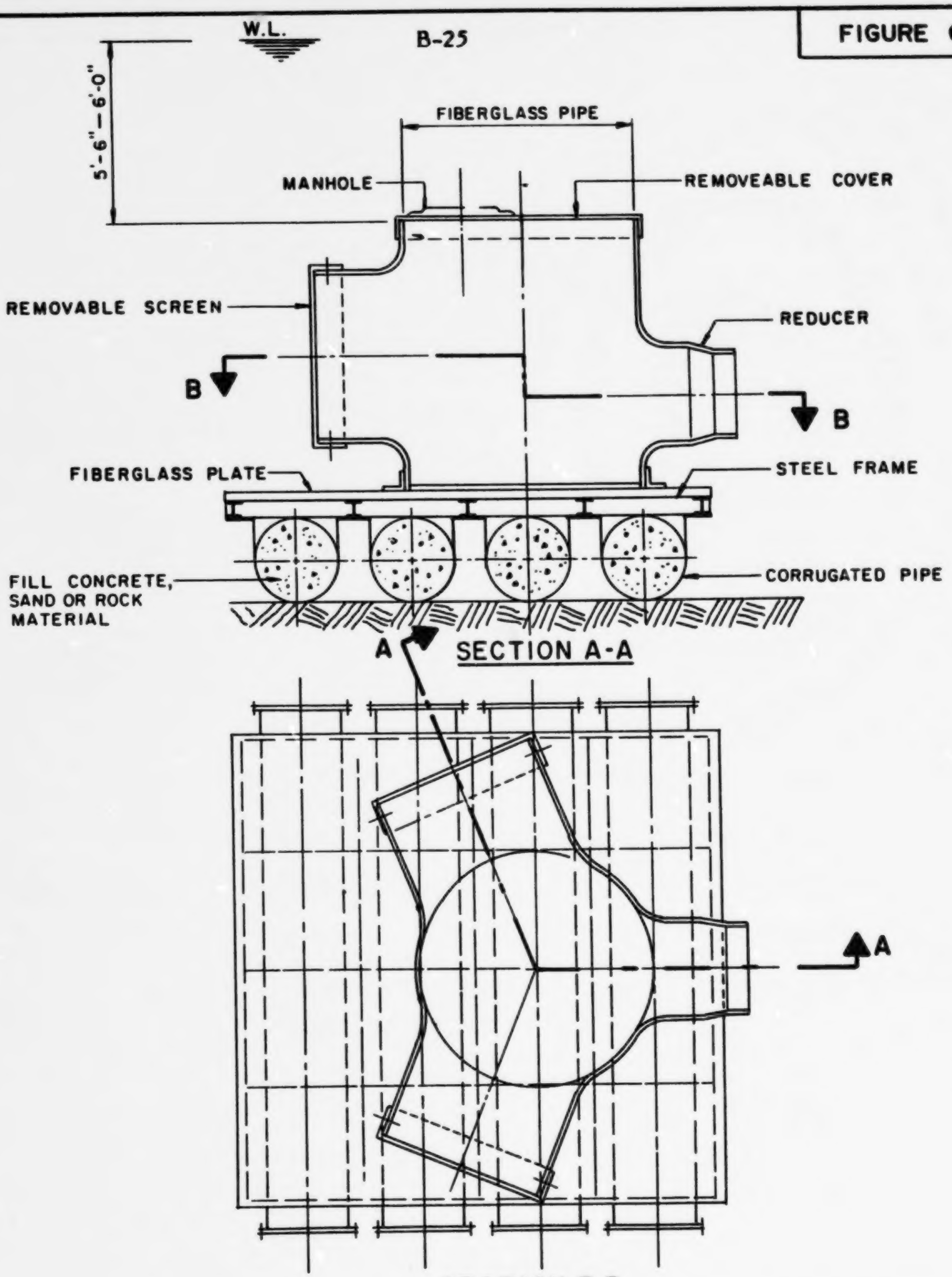
SECTION A-A

NEWFOUNDLAND & LABRADOR HYDRO
SMALL SCALE HYDRO STUDY
SHAWMONT NEWFOUNDLAND LIMITED

TIMBER CRIB INTAKE STRUCTURE ON
STREAM BANK

DESIGNED T. K.
DRAWN R. J. K.
SCALE
DATE FEB., 1979
CONTRACT 1479
FILE NO
APPROVED

FIGURE 6-9

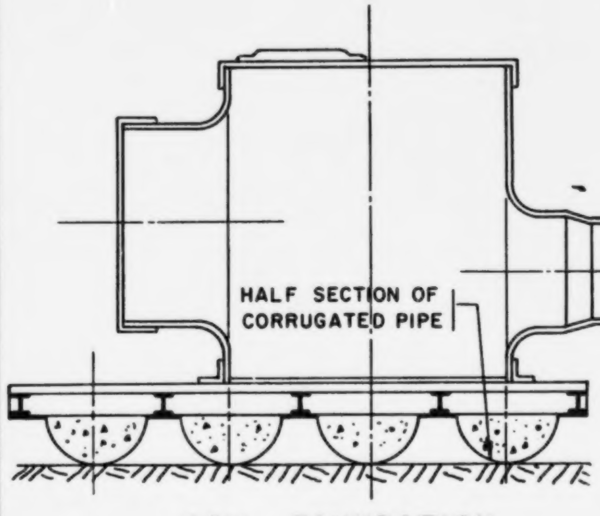

W.L.
5'-6" – 6'-0"
FIBERGLASS PIPE
MANHOLE
REMOVEABLE COVER
REMOVABLE SCREEN
REDUCER
B
B
FIBERGLASS PLATE
STEEL FRAME
FILL CONCRETE, SAND OR ROCK MATERIAL
CORRUGATED PIPE
A
SECTION A-A
A
SECTION B-B

NEWFOUNDLAND & LABRADOR HYDRO
SMALL SCALE HYDRO STUDY
SHAWMONT NEWFOUNDLAND LIMITED

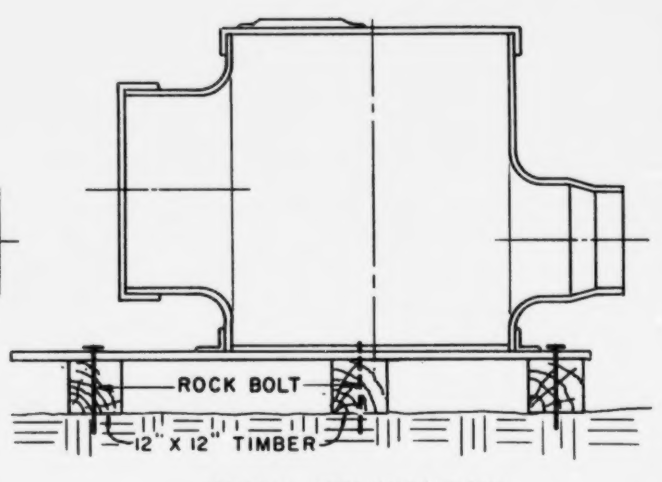
FIBERGLASS INTAKE STRUCTURE

DESIGNED T. K	DRAWN R.J.K.	SCALE NOT TO SCALE	DATE
CONTRACT 1479	FILE NO.		APPROVED

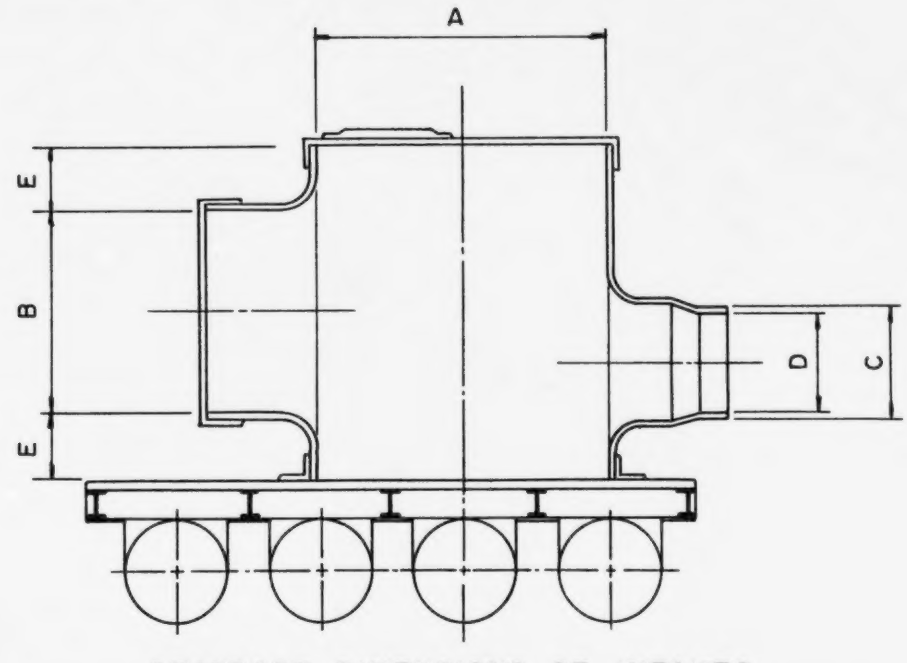
FIGURE 6-10


HALF SECTION OF CORRUGATED PIPE

SOIL FOUNDATION


ROCK BOLT
12" X 12" TIMBER

ROCK FOUNDATION



STANDARD DIMENSIONS OF INTAKES

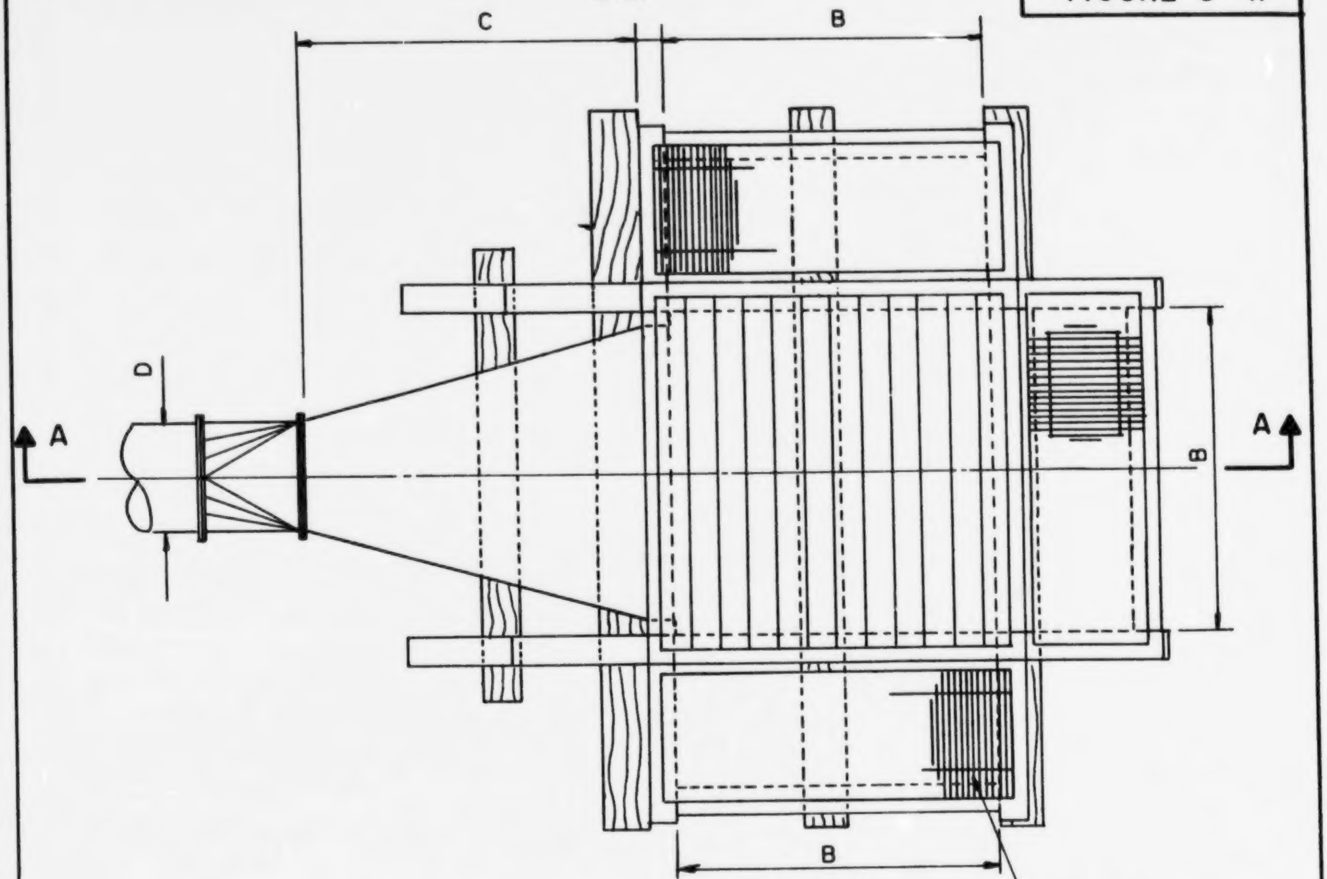
Q INTAKE	A		B		C		D		E	
m^3/sec	cm	(inches)	cm	(inches)	cm	(inches)	cm	(inches)	cm	(inches)
0.25	168	(66)	102	(40)	46	(18)	30	(12)	23	(9)
0.50	168	(66)	91x2	(36x2	61	(24)	46	(18)	23	(9)

NEWFOUNDLAND & LABRADOR HYDRO
SMALL SCALE HYDRO STUDY
SHAWMONT NEWFOUNDLAND LIMITED

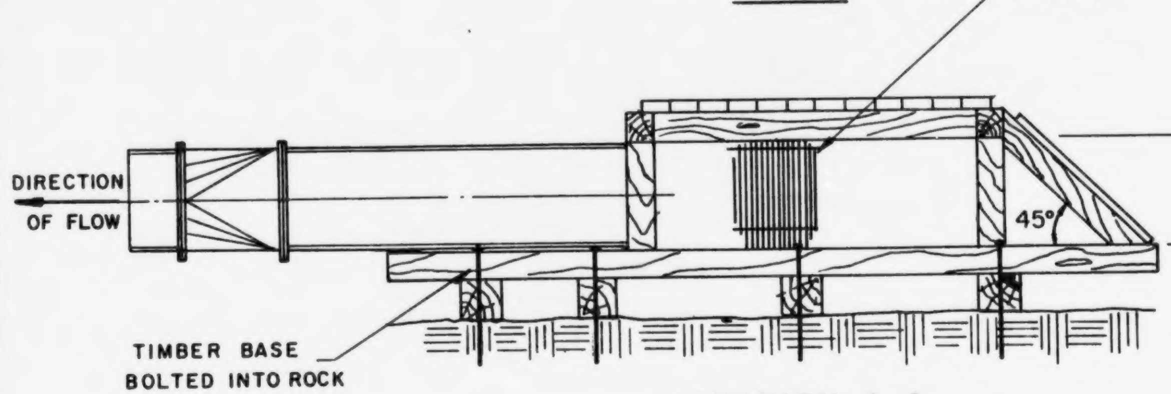
FIBERGLASS INTAKE STRUCTURES

DESIGNED T.K.
DRAWN RJK
SCALE ~
DATE 79-01-
CONTRACT 1479
FILE NO.
APPROVED

FIGURE 6-11


C
B
D
A
A
B
B
SCREEN

PLAN


DIRECTION OF FLOW
A
45°
TIMBER BASE BOLTED INTO ROCK

SECTION A-A

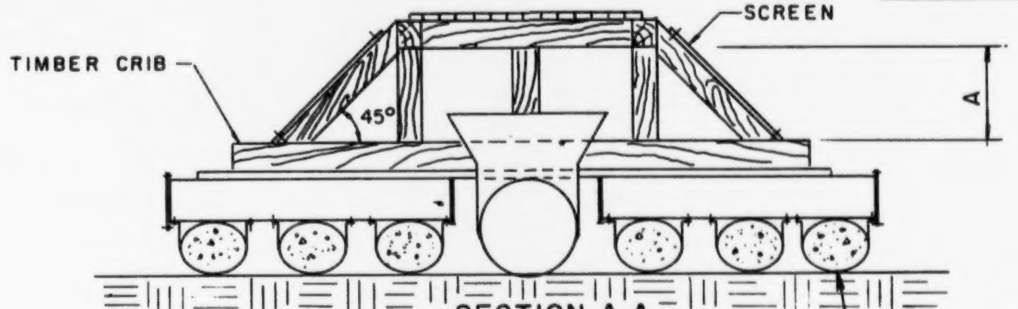
Q INTAKE	A	B	C	D
m³/sec	cm	cm	cm	cm (inches)
2.0	120	170	300	91 (36)
2.5	120	210	300	91 (36)
3.0	120	250	300	107 (42)
3.5	120	300	300	122 (48)
4.0	120	340	300	122 (48)

NEWFOUNDLAND & LABRADOR HYDRO
SMALL SCALE HYDRO STUDY
SHAWMONT NEWFOUNDLAND LIMITED

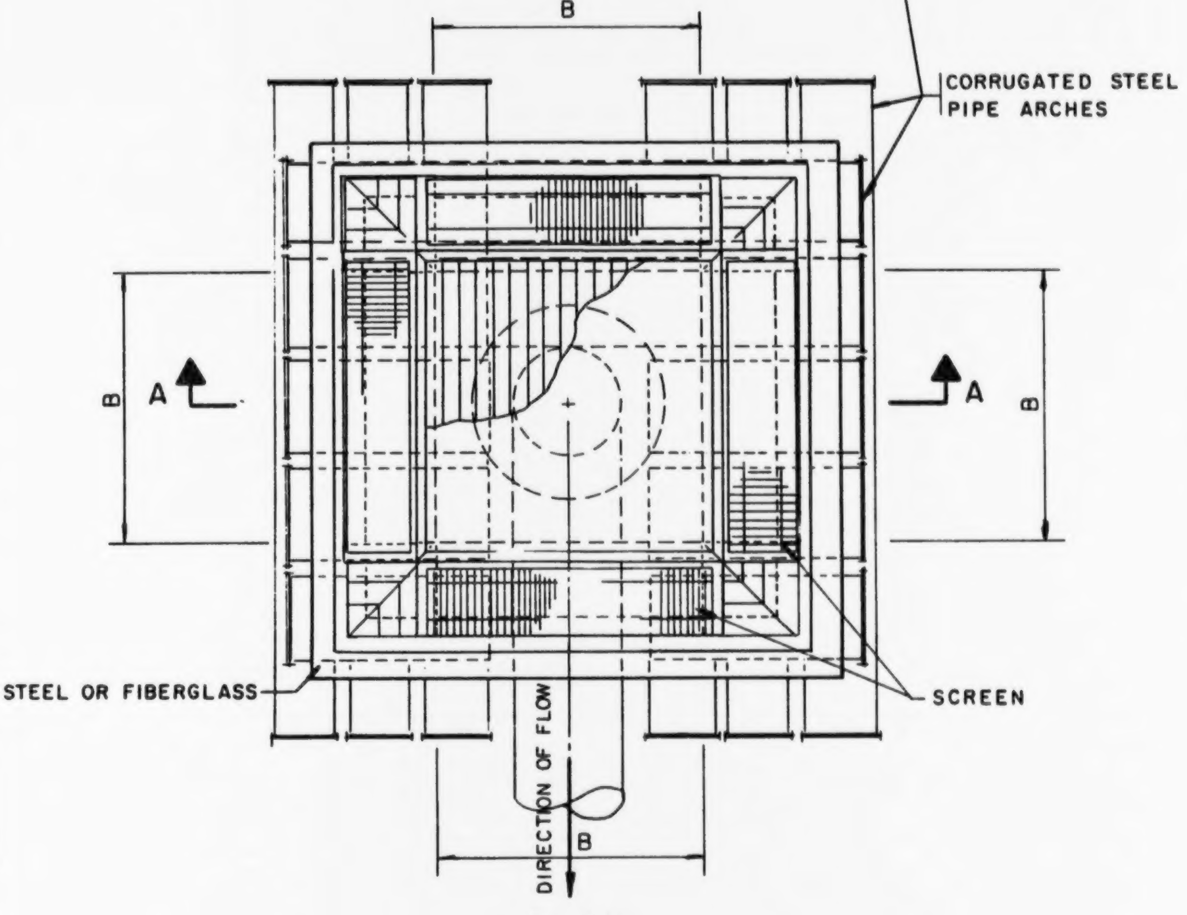
TIMBER CRIB INTAKE STRUCTURE
ROCK FOUNDATION

DESIGNED T. K	DRAWN RJK	SCALE ~	DATE 79-01-
CONTRACT 1479	FILE NO.		APPROVED

FIGURE 6-12


SCREEN
TIMBER CRIB
45°
A

SECTION A-A


B
CORRUGATED STEEL PIPE ARCHES
A
A
B
B
STEEL OR FIBERGLASS
SCREEN
DIRECTION OF FLOW
B

PLAN

Q INTAKE	A	B
m²/sec	cm	cm
2.5	90	210
3.0	90	250
3.5	120	220
4.0	120	250

STANDARD DIMENSIONS OF INTAKES

NEWFOUNDLAND & LABRADOR HYDRO

SMALL SCALE HYDRO STUDY

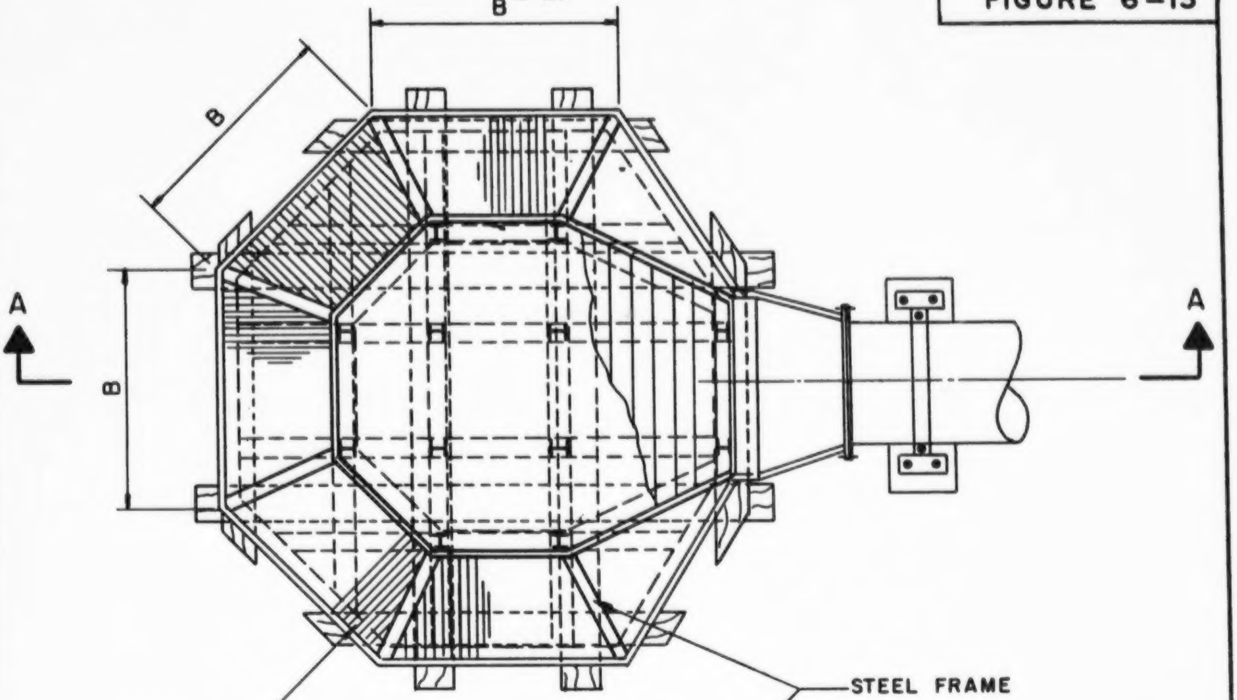
SHAWMONT NEWFOUNDLAND LIMITED

TIMBER CRIB INTAKE STRUCTURE ROCK FOUNDATION

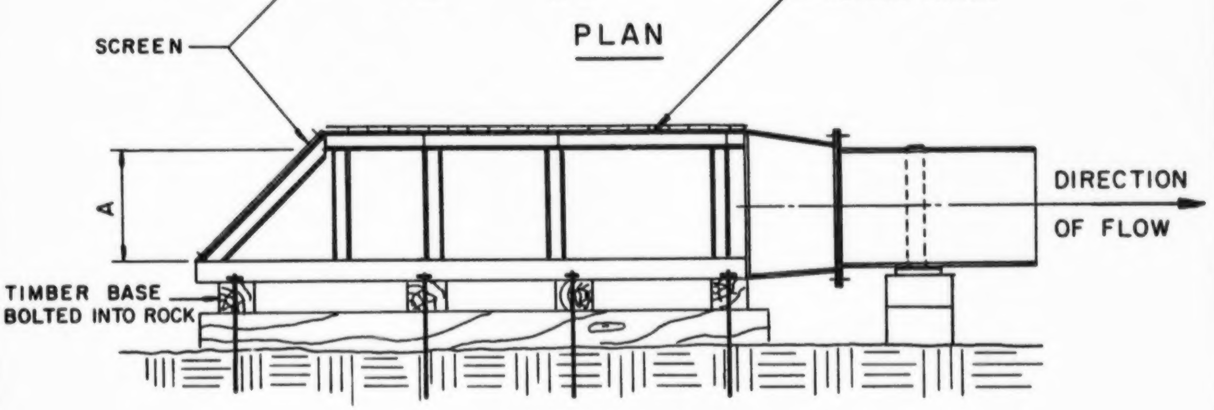
DESIGNED	DRAWN	SCALE	DATE
T. K	RJK	~	79-01-

CONTRACT	FILE NO	APPROVED
1479		

FIGURE 6–13


B
B
B
A
A
STEEL FRAME

PLAN


SCREEN
A
DIRECTION OF FLOW
TIMBER BASE BOLTED INTO ROCK

SECTION A-A

Q INTAKE	A	B
m³/sec	cm	cm
4	120	200
5	120	250
6	120	300

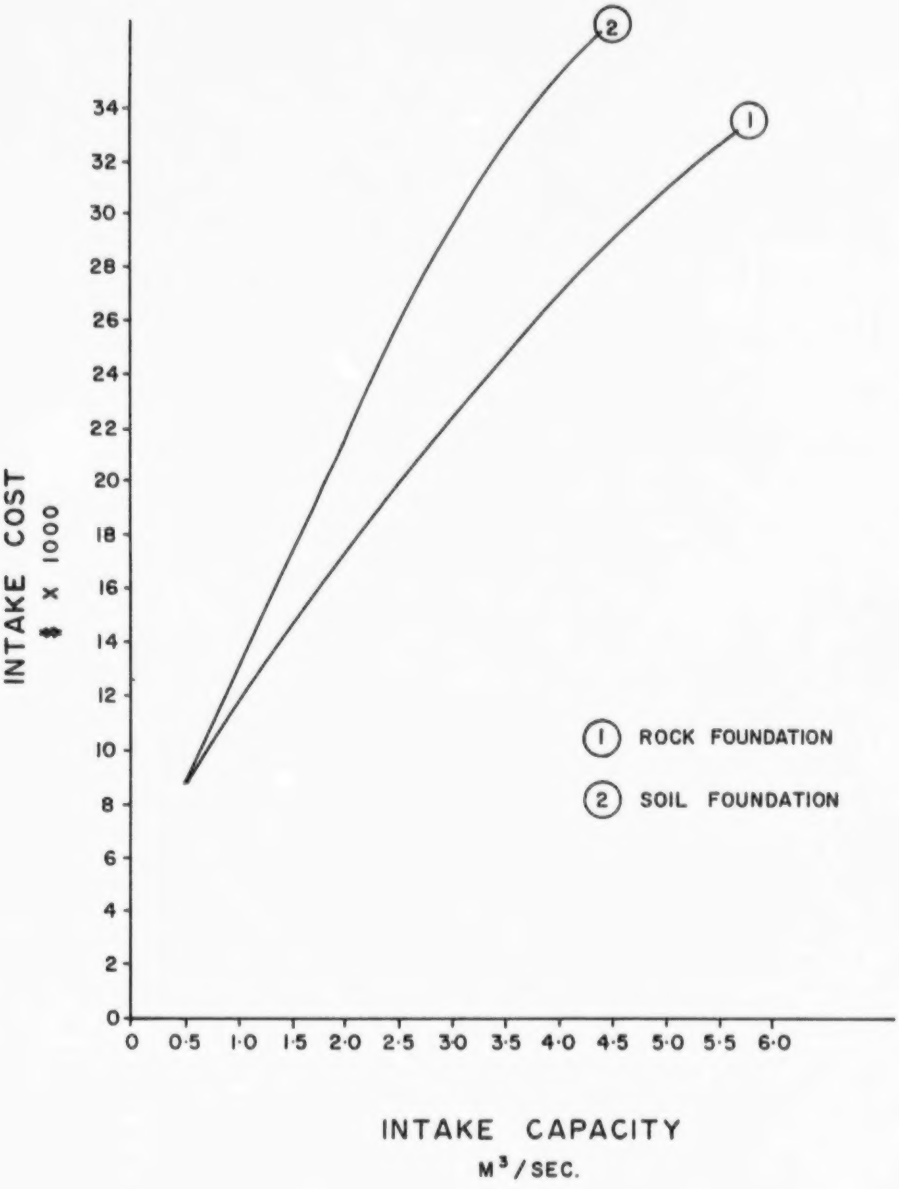
STANDARD DIMENSIONS OF INTAKES

NEWFOUNDLAND & LABRADOR HYDRO
SMALL SCALE HYDRO STUDY
SHAWMONT NEWFOUNDLAND LIMITED

STEEL FRAME CRIB INTAKE STRUCTURE · ROCK FOUNDATION

DESIGNED T.K	DRAWN RJ.K	SCALE ~	DATE 79-01-
CONTRACT 1479	FILE NO	APPROVED	

FIGURE 6 – 14



NEWFOUNDLAND & LABRADOR HYDRO

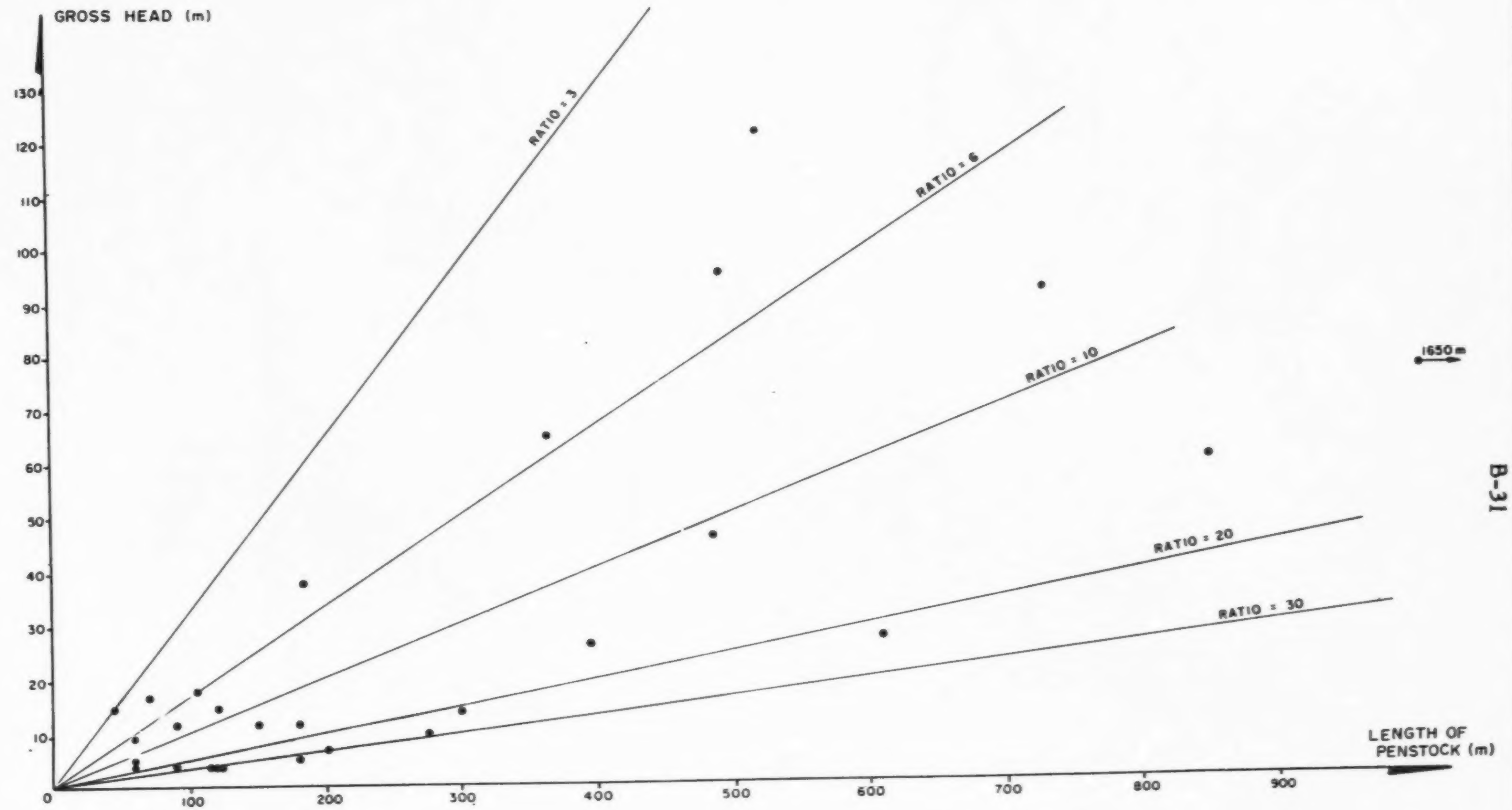
SMALL SCALE HYDRO STUDY

SHAWMONT NEWFOUNDLAND LIMITED

INTAKE CAPACITY vs.
COST OF INTAKE

DESIGNED T.K.	DRAWN W.V.H.	SCALE	DATE MAR., 1979
CONTRACT 1479	FILE NO	APPROVED	

FIGURE 6 — 15



$$\text{RATIO} = \frac{\text{LENGTH OF PENSTOCK}}{\text{GROSS HEAD}}$$

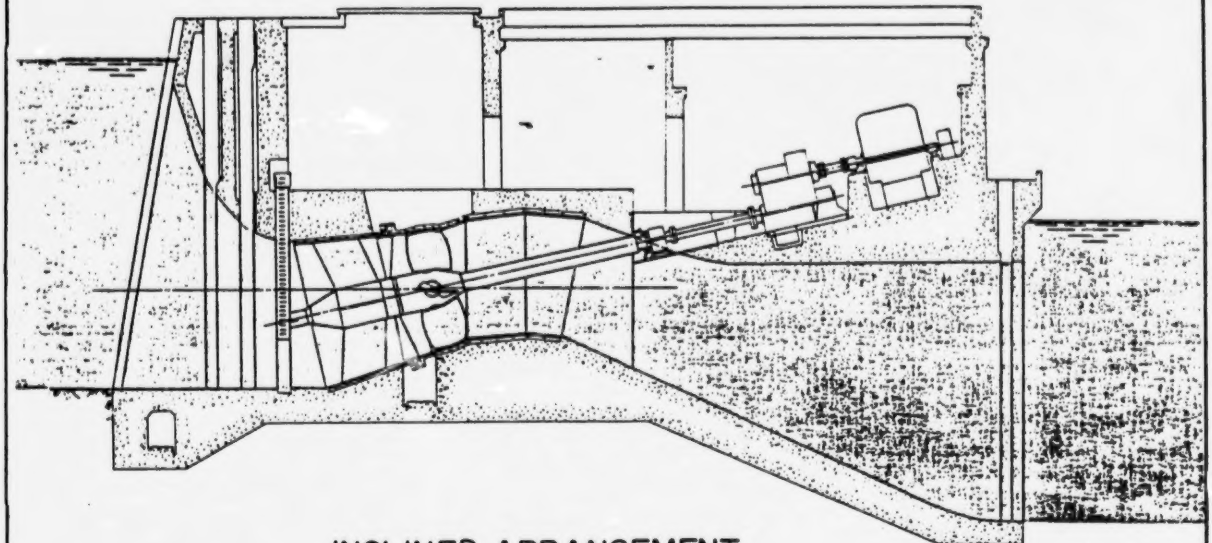
NOTE

POINTS SHOW GROSS HEADS AND PENSTOCK LENGTHS FOR THE 28 FINAL SCHEMES IN TABLES 5-2 AND 5-4

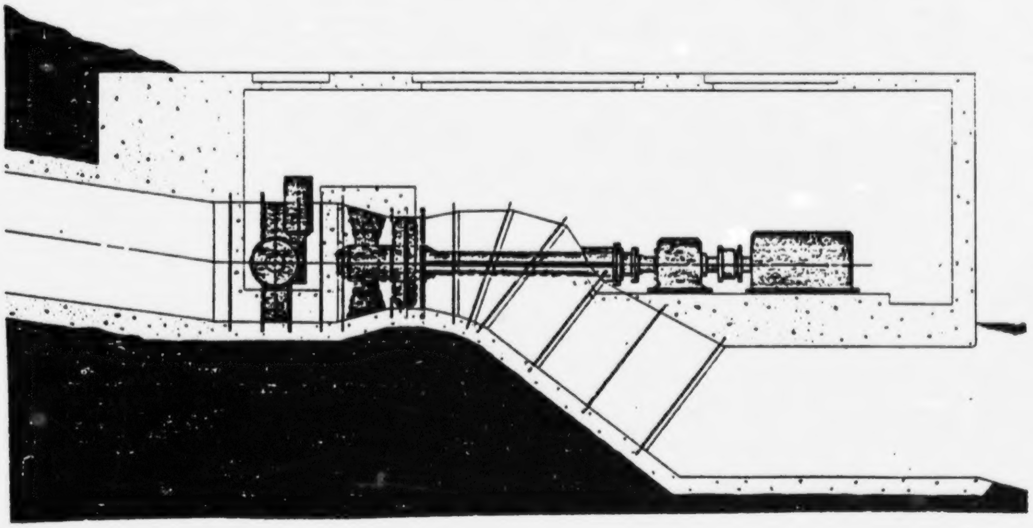
NEWFOUNDLAND & LABRADOR HYDRO
SMALL SCALE HYDRO STUDY
SHAWMONT NEWFOUNDLAND LIMITED

GROSS HEAD v.s.
LENGTH OF PENSTOCK

FIGURE 6-16



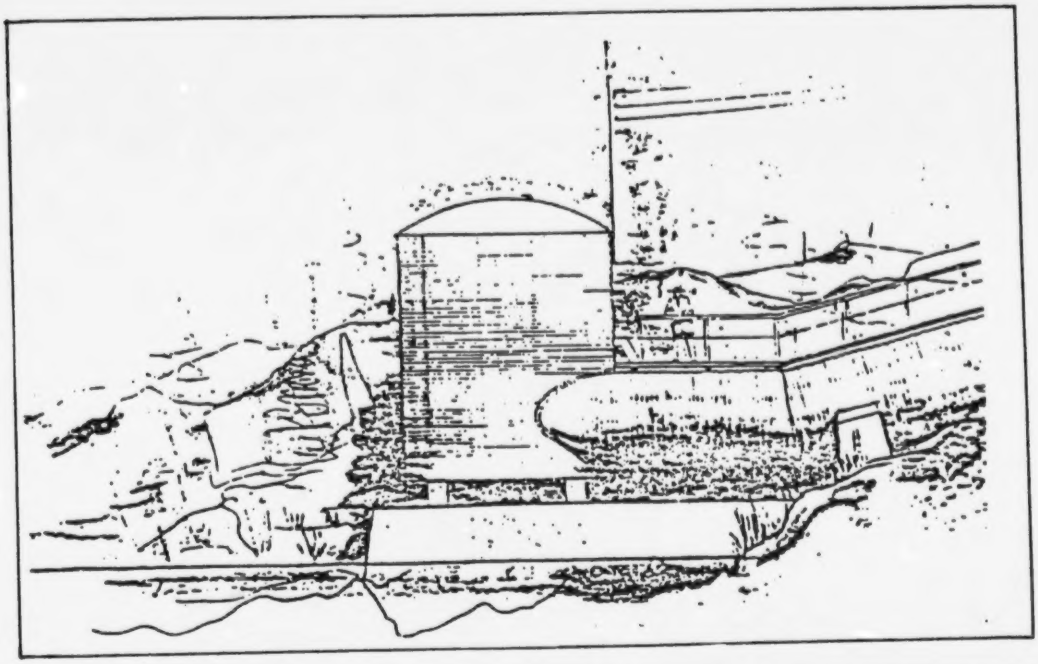
INCLINED ARRANGEMENT

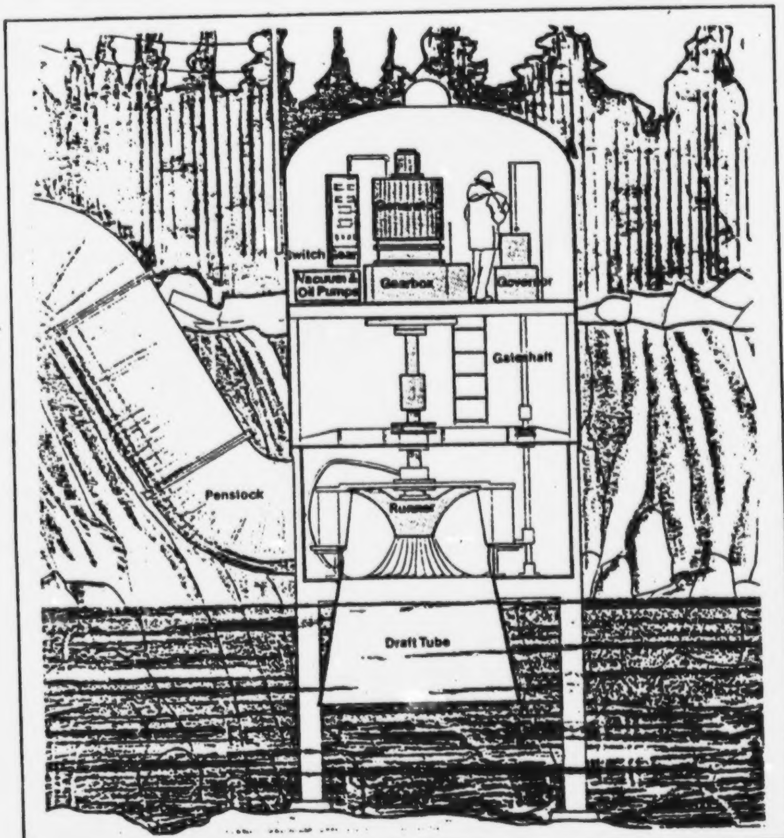


HORIZONTAL ARRANGEMENT

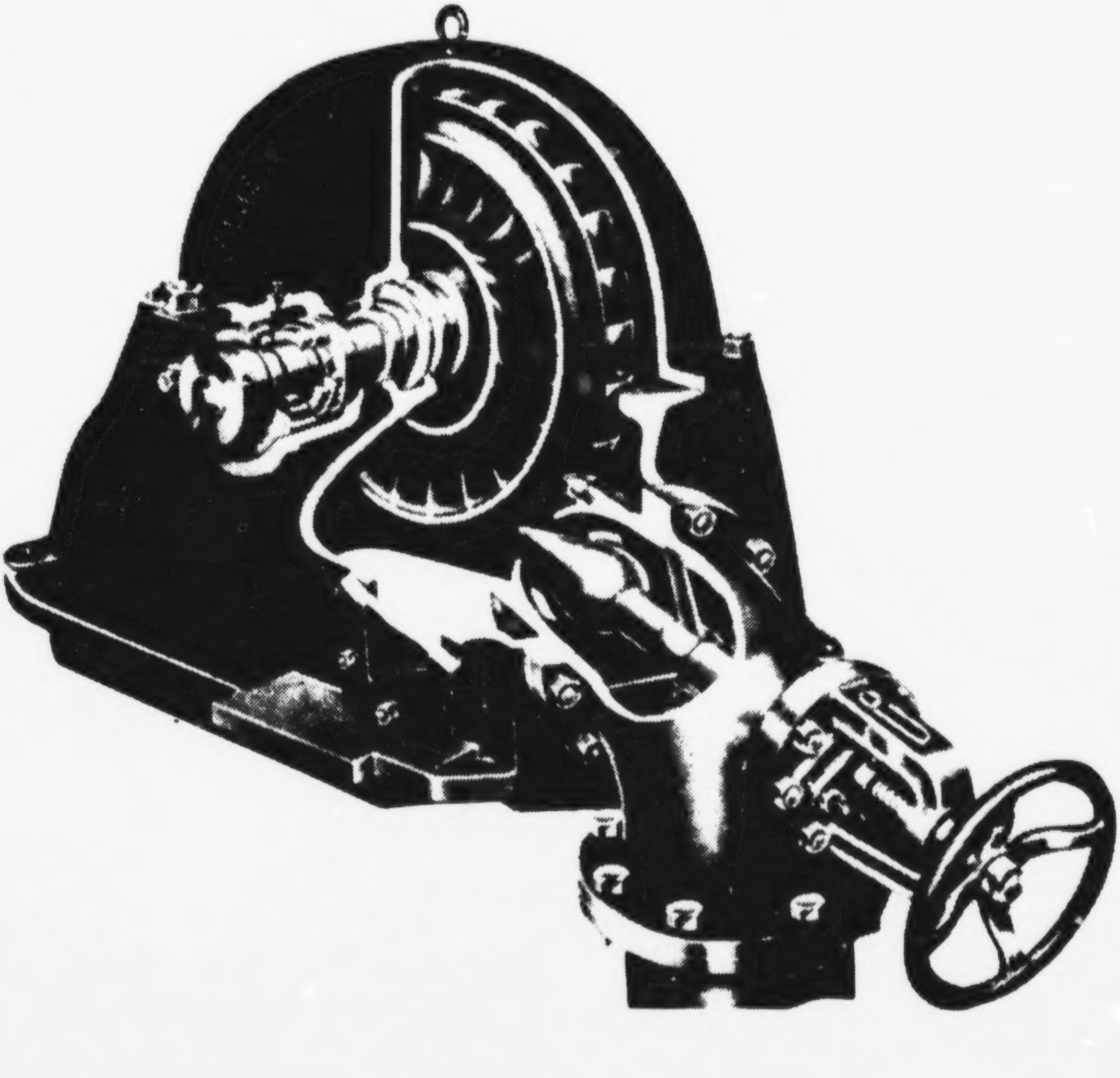
TYPICAL ARRANGEMENT OF TUBE TURBINES

FIGURE 6-17



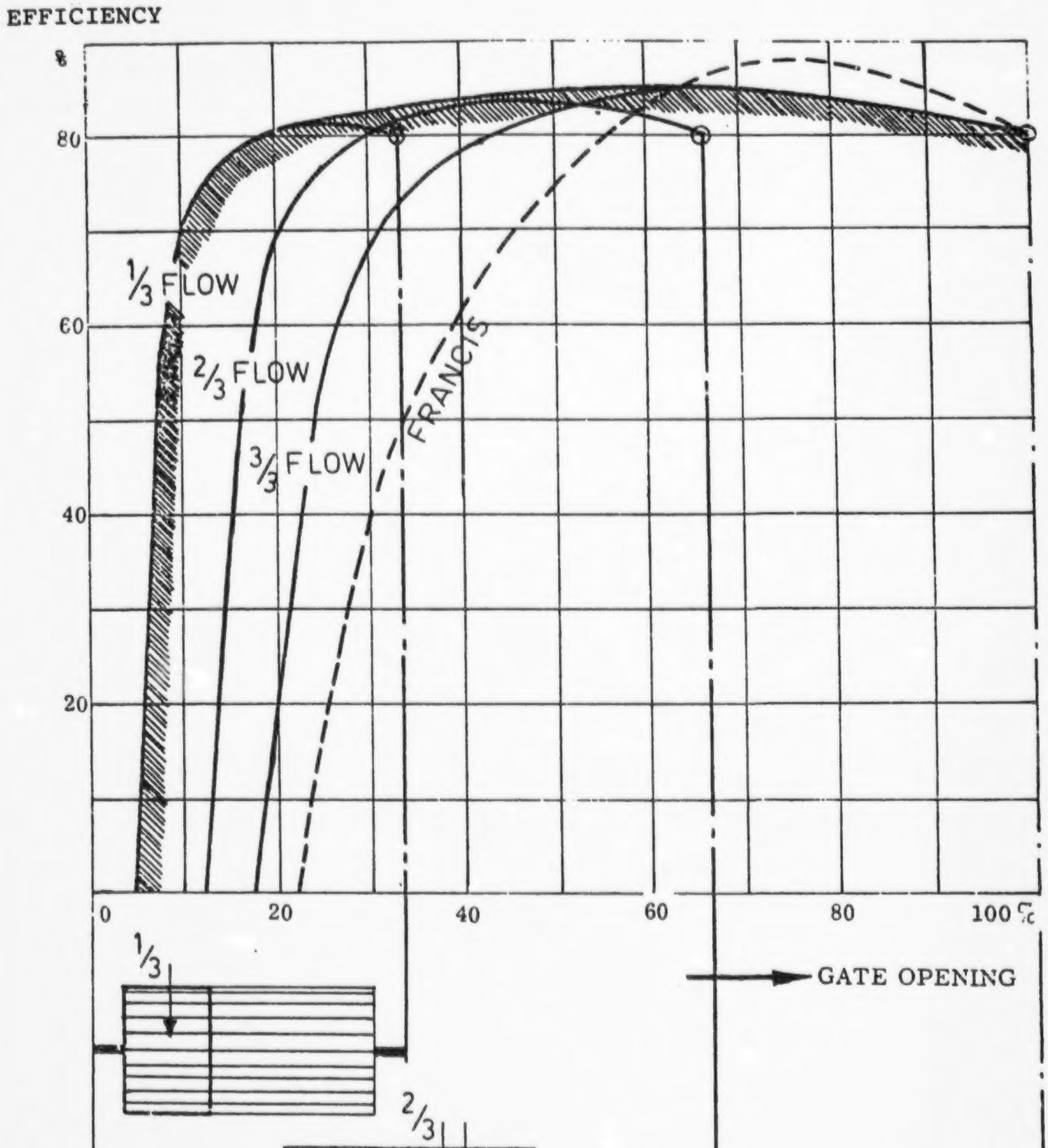

Switch Gear
Vacuum & Oil Pumps
Gearbox
Governor
Gateshaft
Penstock
Runner
Draft Tube

SMALL PREFABRICATED "BARBER" HYDRO-ELECTRIC PLANTS



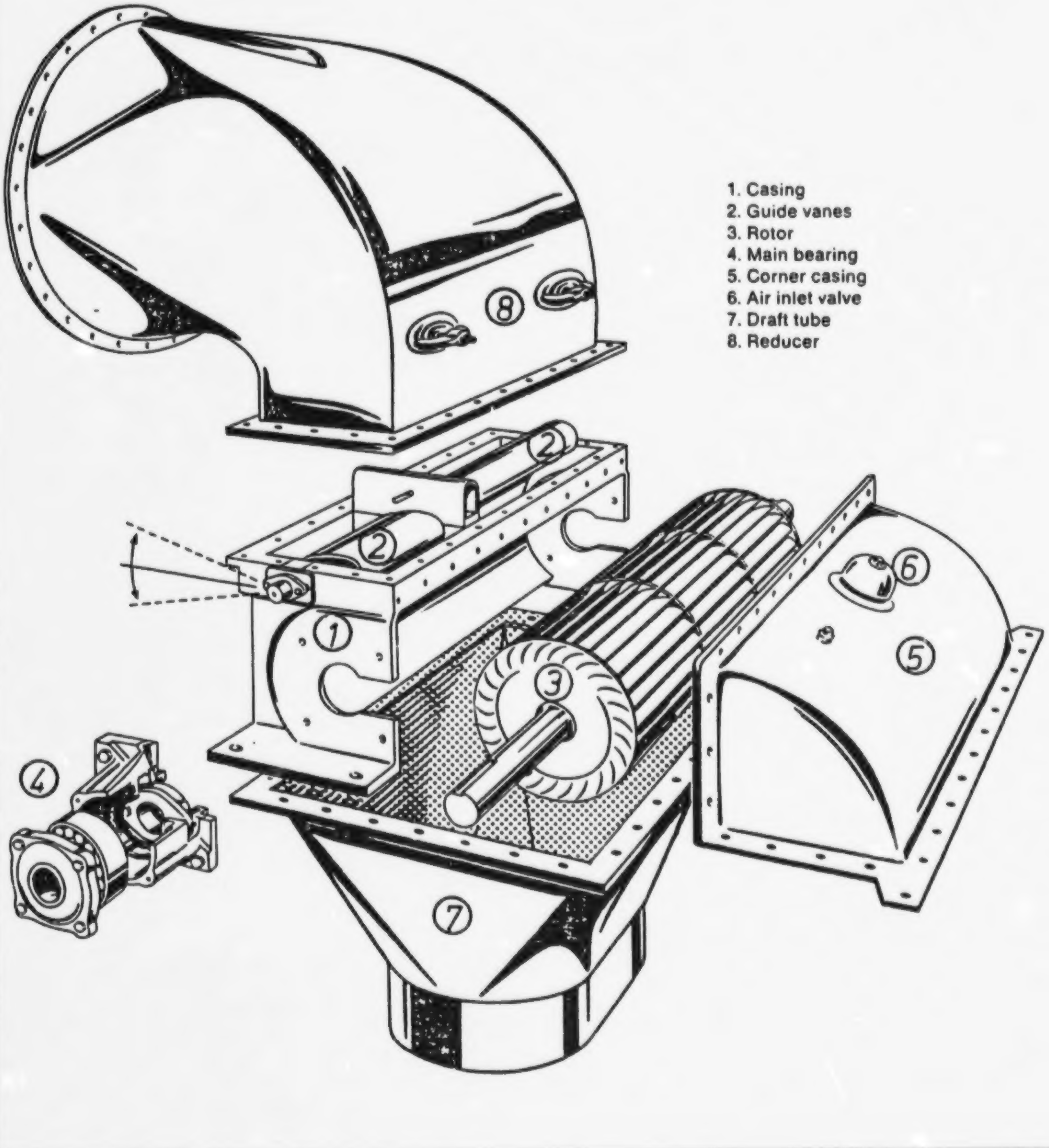
SECTIONAL VIEW OF A TYPICAL
G.G. & GORDON TURGO IMPULSE WHEEL

FIGURE 6-19



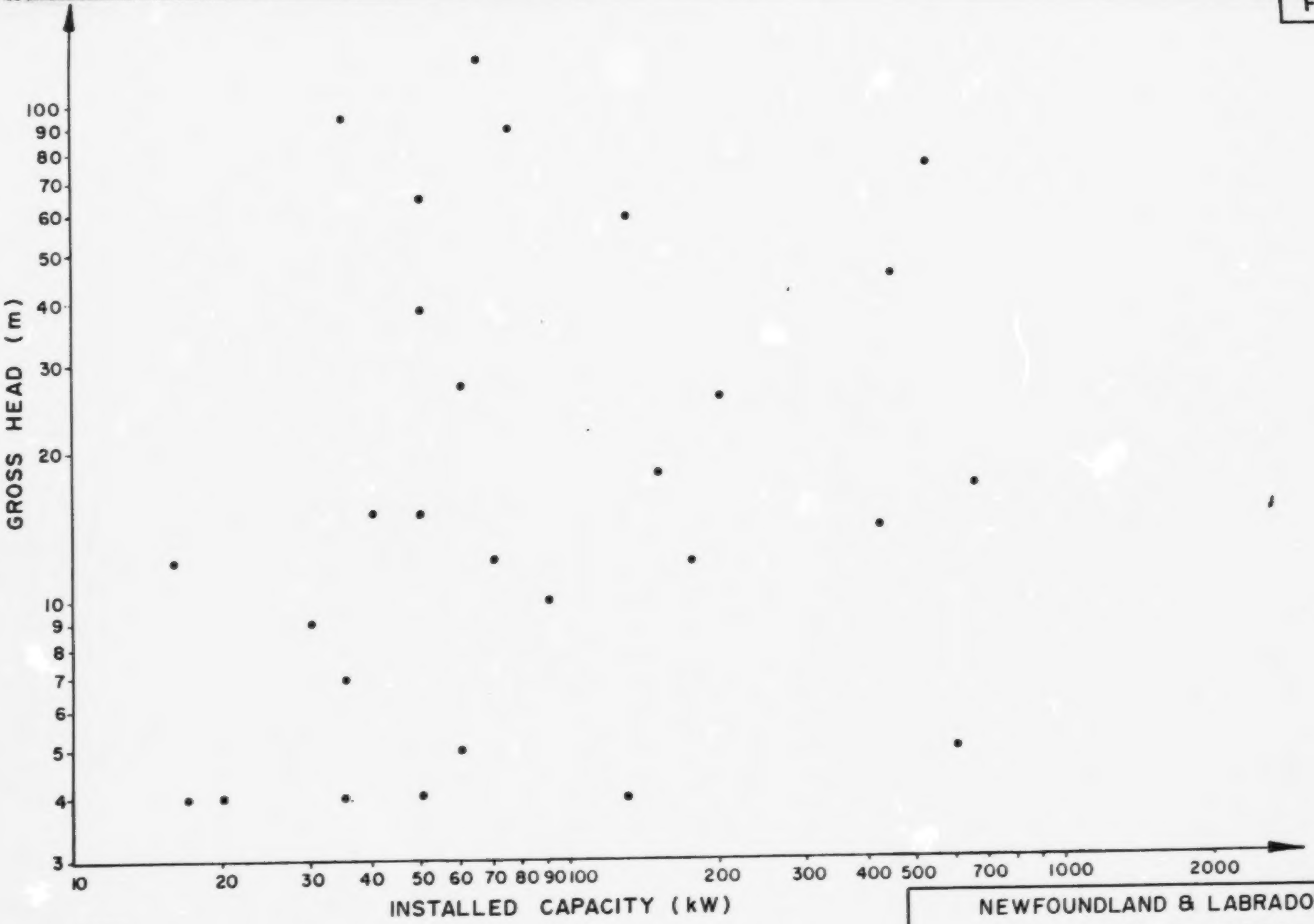
Gate Opening: Ossberger vs Francis

FIGURE 6-20


1. Casing
2. Guide vanes
3. Rotor
4. Main bearing
5. Corner casing
6. Air inlet valve
7. Draft tube
8. Reducer
8
2
2
6
1
5
3
4
7

TWO – SECTION CROSS – FLOW TURBINE ASSEMBLY

FIGURE 6-21



NOTE

POINTS SHOW GROSS HEADS AND CORRESPONDING INSTALLED CAPACITIES FOR THE 28 FINAL SCHEMES IN TABLES 5 – 4 AND 5-2

NEWFOUNDLAND & LABRADOR HYDRO

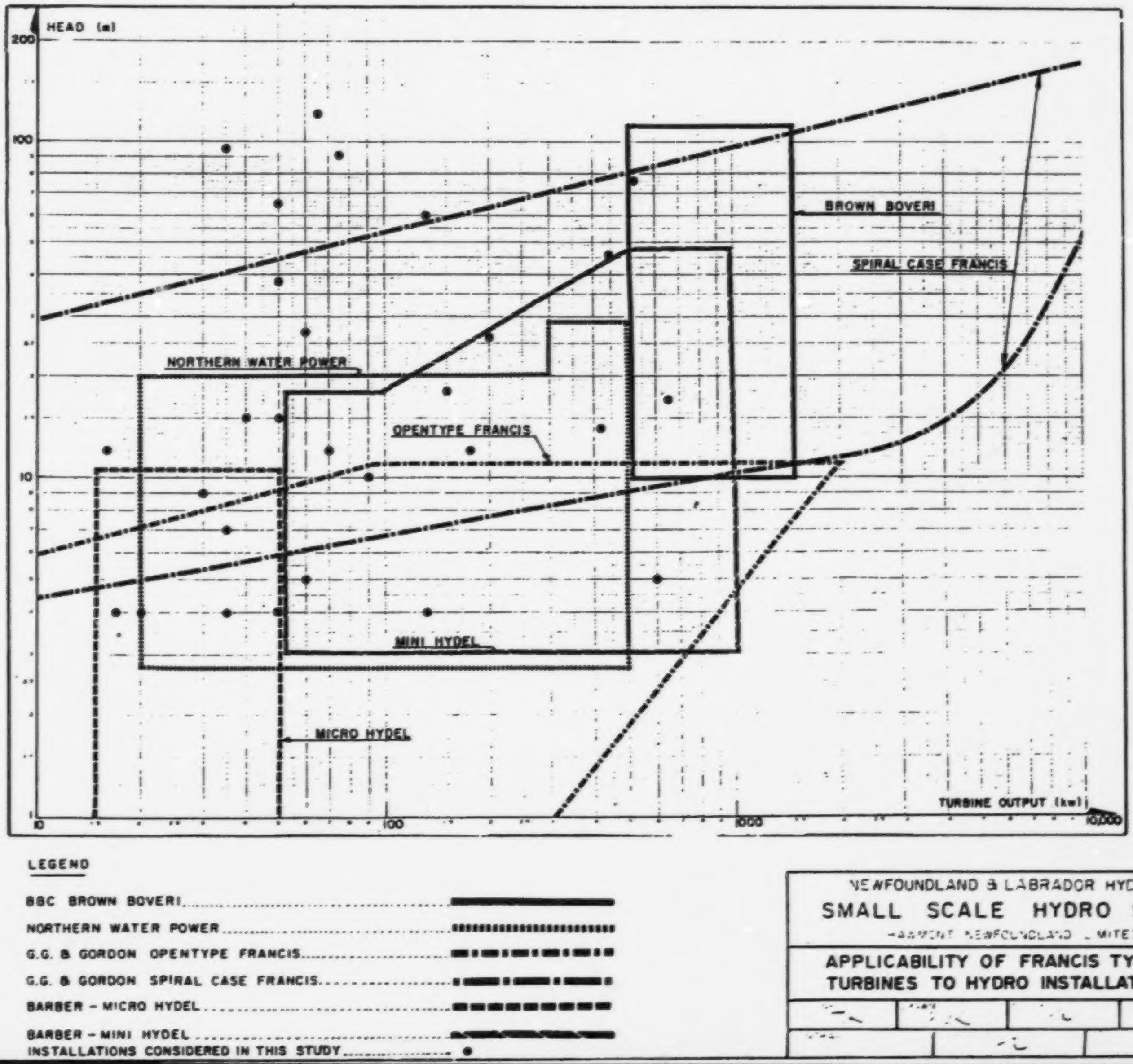
SMALL SCALE HYDRO STUDY

SHAWMONT NEWFOUNDLAND LIMITED

DISTRIBUTION OF TURBINE SIZES

DESIGNED T.K	DRAWN RJK /W.VH.	SCALE ~	DATE 79-01-
CONTRACT 1479	FILE NO.		APPROVED

FIGURE 6 — 22

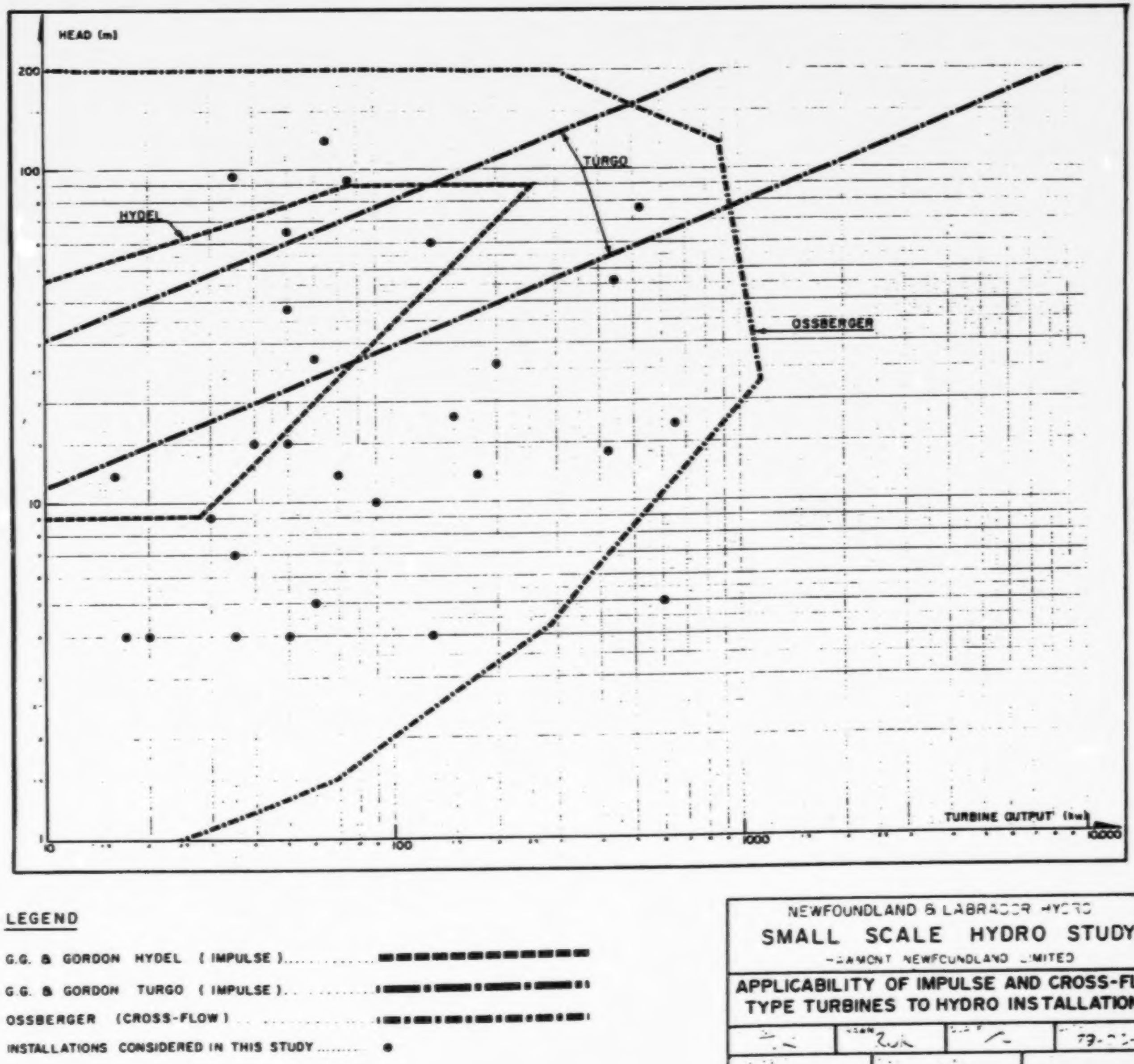


NEWFOUNDLAND & LABRADOR HYDRO
SMALL SCALE HYDRO STUDY
SHAWMONT NEWFOUNDLAND LIMITED

APPLICABILITY OF FRANCIS TYPE
TURBINES TO HYDRO INSTALLATIONS

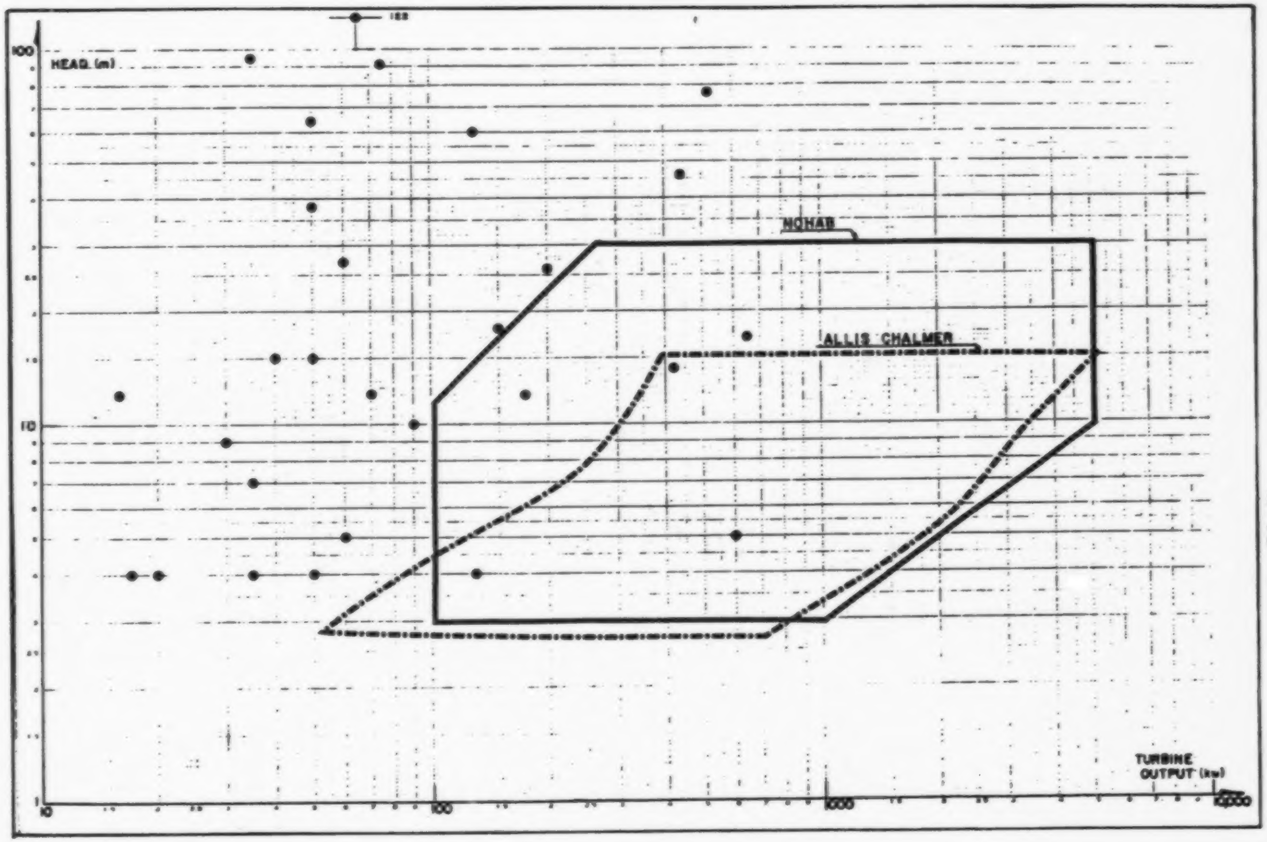
3-02-02

FIGURE 6 – 23



NEWFOUNDLAND & LABRADOR HYDRO
SMALL SCALE HYDRO STUDY
SHAWMONT NEWFOUNDLAND LIMITED

APPLICABILITY OF IMPULSE AND CROSS-FLOW TYPE TURBINES TO HYDRO INSTALLATIONS



LEGEND

ALLIS CHALMER .... ▬ · ▬ · ▬ · ▬

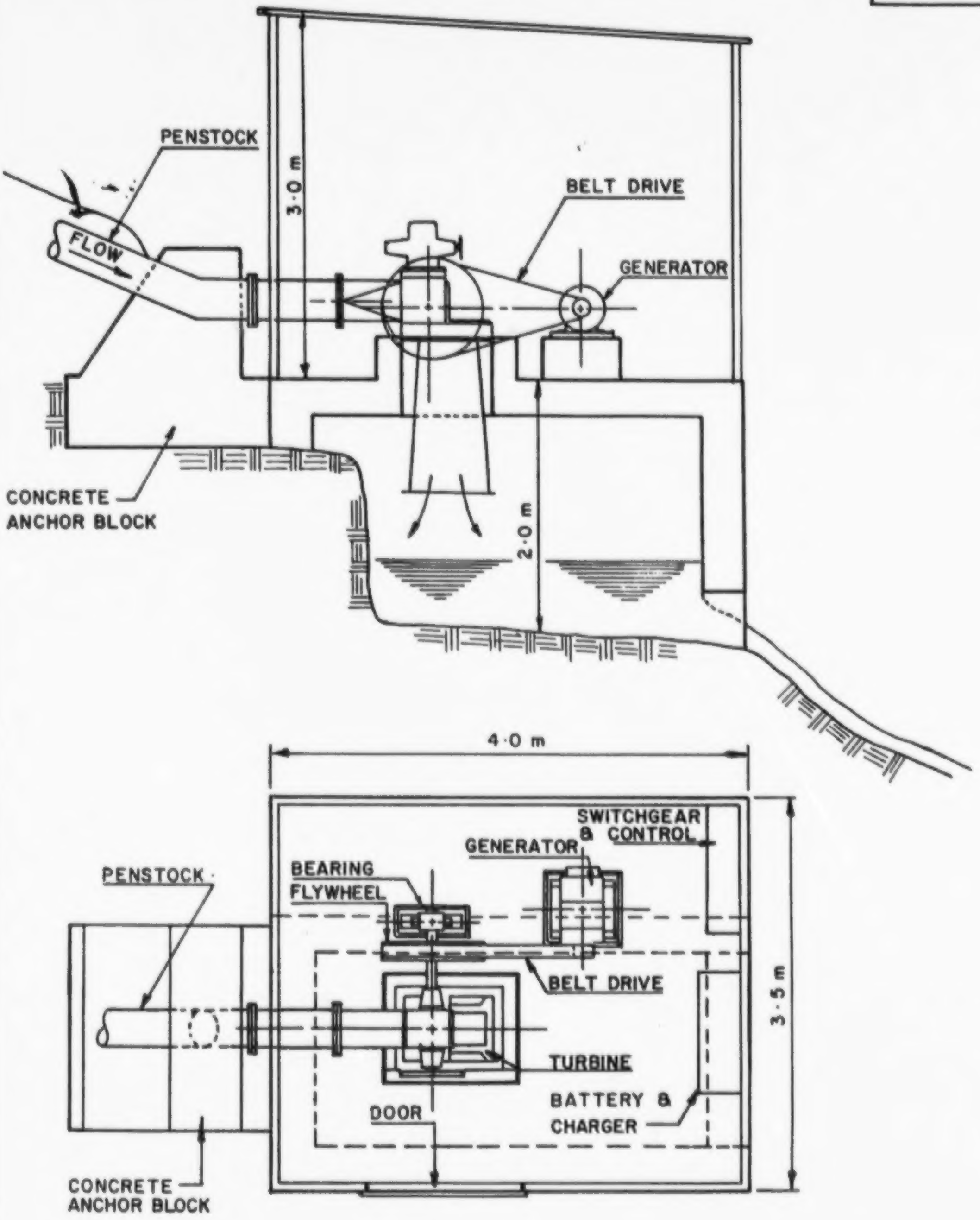
NOHAB .... ▬▬▬▬▬

INSTALLATIONS CONSIDERED IN THIS STUDY .... ●

NEWFOUNDLAND & LABRADOR HYDRO
SMALL SCALE HYDRO STUDY
SHAWMONT NEWFOUNDLAND LIMITED

APPLICABILITY OF PROPELLER TYPE
TURBINES TO HYDRO INSTALLATIONS

FIGURE 6 — 25


PENSTOCK
FLOW
3·0 m
BELT DRIVE
GENERATOR
CONCRETE ANCHOR BLOCK
2·0 m
4·0 m
SWITCHGEAR & CONTROL
GENERATOR
BEARING
FLYWHEEL
PENSTOCK
BELT DRIVE
3·5 m
TURBINE
BATTERY & CHARGER
DOOR
CONCRETE ANCHOR BLOCK

NOTE

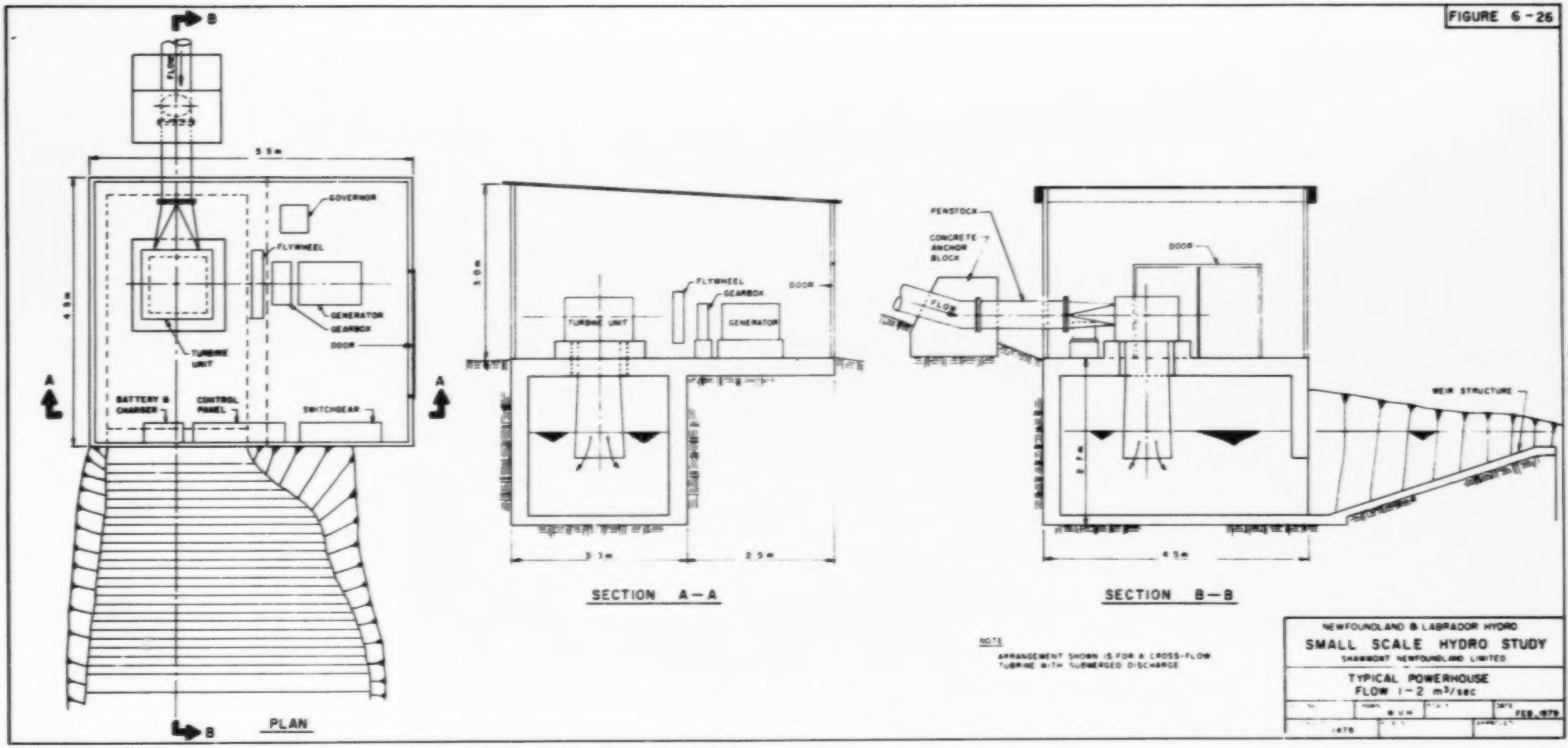
ARRANGEMENT SHOWN IS FOR A CROSS-FLOW TURBINE WITH FREE DISCHARGE

NEWFOUNDLAND & LABRADOR HYDRO
SMALL SCALE HYDRO STUDY
SHAWMONT NEWFOUNDLAND LIMITED

TYPICAL POWERHOUSE
FLOW 0·1-1·0 m³/sec

DESIGNED	DRAWN W.V.H.	SCALE	DATE MAR.,1979
CONTRACT 1479	FILE NO	APPROVED	

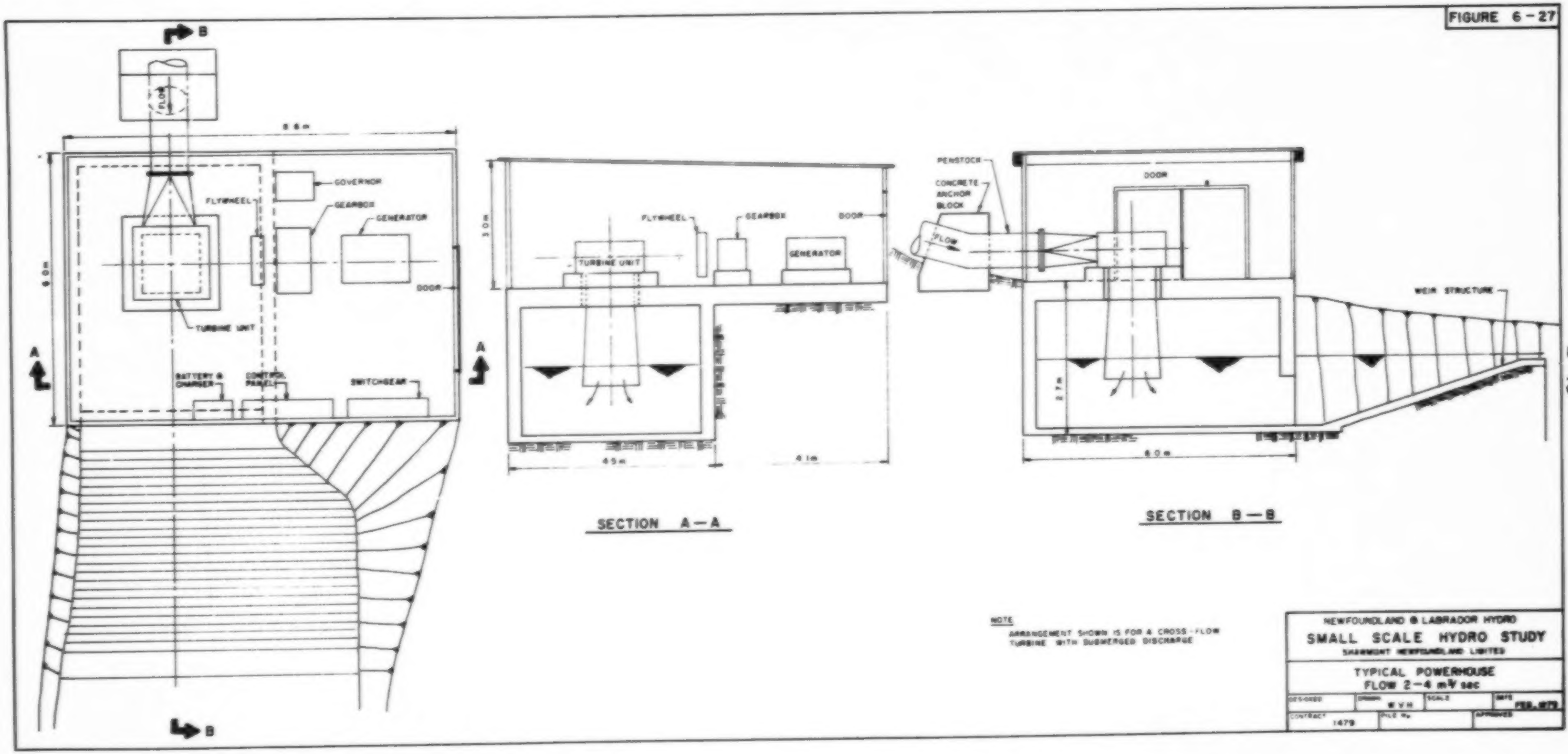
FIGURE 6-26


B
B
A
A
5.5 m
4.9 m
GOVERNOR
FLYWHEEL
GENERATOR
GEARBOX
TURBINE UNIT
DOOR
BATTERY & CHARGER
CONTROL PANEL
SWITCHGEAR
FLOW
PLAN
3.0 m
FLYWHEEL
GEARBOX
GENERATOR
TURBINE UNIT
DOOR
3.1 m
2.5 m
SECTION A–A
PENSTOCK
CONCRETE ANCHOR BLOCK
FLOW
DOOR
WEIR STRUCTURE
2.7 m
4.5 m
SECTION B–B
NEWFOUNDLAND & LABRADOR HYDRO
SMALL SCALE HYDRO STUDY
SHAWMONT NEWFOUNDLAND LIMITED
TYPICAL POWERHOUSE
FLOW 1–2 m³/sec
B.V.H.
FEB. 1979
1479

NOTE

ARRANGEMENT SHOWN IS FOR A CROSS-FLOW TURBINE WITH SUBMERGED DISCHARGE

FIGURE 6 - 27


B
FLOW
8.6 m
6.0 m
GOVERNOR
FLYWHEEL
GEARBOX
GENERATOR
DOOR
TURBINE UNIT
A
BATTERY & CHARGER
CONTROL PANELS
SWITCHGEAR
3.0 m
TURBINE UNIT
FLYWHEEL
GEARBOX
GENERATOR
DOOR
4.5 m
4.1 m
PENSTOCK
CONCRETE ANCHOR BLOCK
FLOW
DOOR
2.7 m
6.0 m
WEIR STRUCTURE

SECTION A — A

SECTION B — B

NOTE
ARRANGEMENT SHOWN IS FOR A CROSS-FLOW TURBINE WITH SUBMERGED DISCHARGE

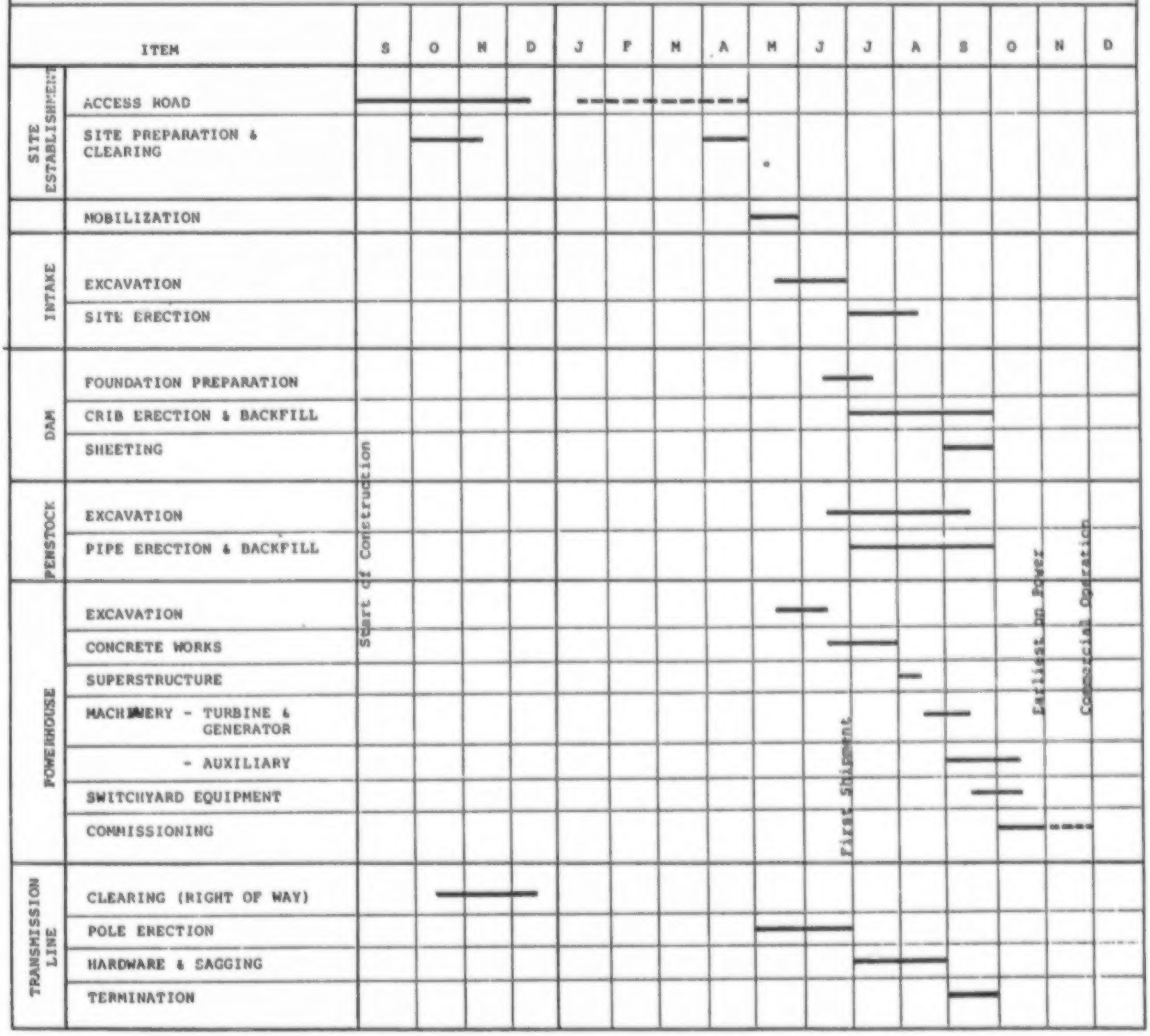
NEWFOUNDLAND & LABRADOR HYDRO
SMALL SCALE HYDRO STUDY
SHAWMONT NEWFOUNDLAND LIMITED

TYPICAL POWERHOUSE
FLOW 2—4 m³/ sec

DESIGNED | DRAWN M.V.H. | SCALE | DATE FEB. 1979
CONTRACT 1479 | FILE No. | APPROVED

Figure 6-28

TYPICAL CONSTRUCTION SCHEDULE FOR SMALL SCALE HYDRO DEVELOPMENT



APPENDIX C

ECONOMIC POTENTIAL AND RODDICKTON MINI-HYDRO ECONOMIC EVALUATION

ECONOMIC POTENTIAL

The inventory, screening and identification of 28 potential hydro developments reflects consideration only of technical viability. The true potential cannot be assessed realistically without some analysis of the probable cost and benefits attributable to each development. It must be recognized that without further study, and detailed studies can hardly be justified for such small-scale projects, neither costs nor benefits can be estimated accurately.

Order of magnitude capital costs for the 28 developments were estimated and tabulated in Table 1. Four major cost components were identified:

1. Access road and transmission line – this was relatively easy to estimate.
2. For the hydro equipment package, Gordon's formula was used and gives reasonable estimates of cost.
3. For the civil works, the scope of work cannot be well defined since no site inspection or engineering layouts were done for any of the 28 sites. 'Ball park' estimates were therefore developed for the civil works.
4. For engineering, contingencies and interest during construction, estimates are generally a percentage of the above three items.

The benefits attributable to the hydro plants are measured and defined in terms of fuel cost savings at the diesel generating plant. The method of assessing the annual plant generation was described earlier. Limitations in the available hydrological data and the inevitable simplified assumptions used in these energy assessments mean that an accuracy of better than perhaps ± 20 % can be expected.

The value of the benefits are listed in Table 2 and are calculated on the following basis:

1. Fuel cost per kWh were calculated from the estimated delivered prices for diesel fuel (Table 3) and multiplied by the annual hydro energy to give an annual benefit value. This is the benefit for potentially the first year of operation (1980-1981).
2. To prepare a benefit value for comparison with the capital costs a discounting calculation was made and a present value determined. A 20-year analysis period was assumed and the annual amount of energy generated was assumed constant.

The economic analysis showed that for the 28 sites investigated two are probably viable and these will produce about 4.1 GWh, eleven are possibly viable and these will produce about 8.8 GWh, and fifteen are not viable and these showed a potential of 5.7 GWh. Table 4 summarizes the results.

ORDER OF MAGNITUDE CAPITAL COSTS (1980 Dollars) TABLE 1

HYDRO SCHEME	ACCESS ROAD (1)	TRANSMISSION LINE (2)	HYDRO PACKAGE EQUIPMENT (5)	CIVIL WORKS (6)	TOTAL CAPITAL COST (7) (thousands of dollars)
A. NEWFOUNDLAND					
1. Burgeo	77,000	153,000	407,000	560,000	1,500 - 2,000
2. Croque	-	42,000	53,000	200,000	300 - 400
3. Flower's Cove	139,000	166,000 (3)	590,000	1,300,000	2,000 - 3,000
4. Francois	106,000	68,000	50,000	340,000	500 - 750
5. Grand Bruit	-	-	59,000	170,000	300 - 400
6. Grandois	-	-	34,000	150,000	200 - 300
7. Grey River	258,000	165,000	29,000	100,000	500 - 750
8. Harbour Deep	92,000	59,000	143,000	350,000	700 - 900
9. La Poile	211,000	108,000	42,000	360,000	700 - 950
10. McCallum	281,000	180,000	71,000	150,000	700 - 900
11. Monkstown	10,000	6,000	51,000	210,000	300 - 500
12. Petite Forte	69,000	44,000	87,000	200,000	400 - 600
13. Petites	244,000	157,000	60,000	200,000	700 - 900
14. Rencontre East	264,000	170,000	41,000	360,000	750 - 1,050
15. Roddickton	80,000	112,000 (4)	219,000	450,000	1,000 - 1,500
16. St. Anthony	43,000	142,000 (4)	206,000	970,000	1,200 - 1,700
17. South East Bight	79,000	51,000	59,000	200,000	400 - 600
18. Westport	3,000	123,000	183,000	550,000	750 - 1,100
B. LABRADOR					
19. Cartwright	116,000	64,000	85,000	270,000	500 - 750
20. Charlottetown	142,000	91,000	97,000	300,000	600 - 900
21. Fox Harbour	178,000	85,000	118,000	450,000	750 - 1,000
22. L'Anse-au-Loup	27,000	34,000	321,000	900,000	1,200 - 1,650
23. Makkovik	238,000	153,000	154,000	570,000	1,000 - 1,500
24. Mary's Harbour	63,000	40,000	219,000	650,000	1,000 - 1,500
25. Paradise River	112,000	72,000	72,000	250,000	500 - 750
26. Port Hope Simpson	112,000	72,000	123,000	450,000	900 - 1,200
27. Postville	231,000	148,000	112,000	300,000	800 - 1,000
28. Rigolet	148,000	95,000	65,000	350,000	600 - 900

NOTES:
1. Based on a unit cost of $33,000/km
2. Cost includes transmission line @ $17,800/km & control communications cable @ $4,000/km
3. Cost includes installation of control communications cable on existing 3-phase transmission line.
4. Includes cost of upgrading a section of existing 1-phase transmission line to 3-phase, & installation of control communications cable.
5. Based on formula derived by Gordon and adjusted to 1980 Canadian dollars.
6. Very approximate estimate
7. Equals sum of the listed component costs plus an allowance for engineering, contingencies and interest during construction. Expressed as a range to indicate margin of accuracy.

TABLE 2

ENERGY AND COST/BENEFIT COMPARISONS

HYDRO SCHEME	INSTALLED HYDRO CAPACITY, kw	ANNUAL ENERGY GENERATION kwh	ANNUAL VALUE OF FUEL DISPLACED BY HYDRO (1980 dollars)	VALUE OF FUEL DISPLACED OVER 20 YEAR LIFE OF HYDRO SCHEME (1980-2000) (1)	TOTAL CAPITAL COST (thousands of dollars) (2)
A. NEWFOUNDLAND					
1. Burgeo	650	3,316,000	172,000	2,300,000	1,500 - 2,000
2. Croque	17	107,000	10,000	134,000	300 - 400
3. Flower's Cove	600	2,038,000	101,000	1,350,000	2,000 - 3,000
4. Francois	75	429,000	44,000	588,000	500 - 750
5. Grand Bruit	30	177,000	22,000	294,000	300 - 400
6. Grandois	16	85,000	11,000	147,000	200 - 300
7. Grey River	35	247,000	24,000	321,000	500 - 750
8. Harbour Deep	150	756,000	65,000	869,000	700 - 900
9. La Poile	50	298,000	32,000	428,000	700 - 950
10. McCallum	50	326,000	28,000	374,000	700 - 900
11. Monkstown	50	300,000	26,000	348,000	300 - 500
12. Petite Forte	35	158,000	17,000	227,000	400 - 600
13. Petites	40	250,000	32,000	428,000	700 - 900
14. Rencontre East	65	408,000	50,000	668,000	750 - 1,050
15. Roddickton	440	1,480,000	80,000	1,070,000	1,000 - 1,500
16. St. Anthony	520	1,866,000	86,000	1,050,000	1,200 - 1,700
17. South East Bight	20	85,000	11,000	147,000	400 - 600
18. Westport	175	858,000	58,000	775,000	750 - 1,100
B. LABRADOR					
19. Cartwright	130	575,000	50,000	668,000	500 - 750
20. Charlottetown	70	315,000	30,000	401,000	600 - 900
21. Fox Harbour	60	340,000	40,000	535,000	750 - 1,000
22. L'Anse-au-Loup	420	1,403,000	85,000	1,136,000	1,200 - 1,650
23. Makkovik	200	997,000	79,000	1,056,000	1,000 - 1,500
24. Mary's Harbour	130	678,000	64,000	856,000	1,000 - 1,500
25. Paradise River	35	194,000	18,000	241,000	500 - 750
26. Port Hope Simpson	90	423,000	48,000	642,000	900 - 1,200
27. Postville	50	314,000	37,000	495,000	800 - 1,000
28. Rigolet	60	280,000	44,000	588,000	600 - 900

(1) Expressed as a present value (at the assumed 1980-81 in service date) based on discount rate of 12% and an annual escalation rate of 7.5% in fuel prices

(2) Order of magnitude capital cost (From Table 7-1)

DIESEL PLANT FUEL COSTS

TABLE 3

DIESEL PLANT	DIESEL PLANT FUEL CONSUMPTION, kwh/gal.	COST OF DIESEL FUEL 1980 dollars/gal.	UNIT FUEL COST (cents/kwh)
A. NEWFOUNDLAND			
1. Burgeo	15	0.780	5.2
2. Croque	7	0.656	9.4
3. Flower's Cove	13	0.645	5.0
4. Francois	7	0.716	10.2
5. Grand Bruit	7	0.861	12.3
6. Grandois	7	0.861	12.3
7. Grey River	8	0.780	9.8
8. Harbour Deep	10	0.861	8.1
9. La Poile	8	0.861	10.8
10. McCallum	10	0.861	8.6
11. Monkstown	10	0.861	8.6
12. Petite Forte	8	0.861	10.8
13. Petites	7	0.886	12.7
14. Recontre East	7	0.861	12.3
15. Roddickton	12	0.645	5.4
16. St. Anthony	14	0.645	4.6
17. South East Bight	7	0.861	12.3
18. Westport	10	0.678	6.8
B. LABRADOR			
19. Cartwright	11	0.961	8.7
20. Charlottetown	10	0.946	9.5
21. Fox Harbour	8	0.946	11.8
22. L'Anse-au-Loup	12	0.729	6.1
23. Makkovik	12	0.946	7.9
24. Mary's Harbour	10	0.946	9.5
25. Paradise River	10	0.946	9.5
26. Port Hope Simpson	9	1.02	11.3
27. Postville	9	0.946	10.5
28. Rigolet	6	0.946	15.8

TABLE 4

VIABILITY OF POTENTIAL DEVELOPMENTS

	Probably Viable	Possibly Viable	Not Viable
	Burgeo Harbour Deep	Francois Grand Bruit Monkstown Recontre Roddickton St. Anthony Westport Cartwright L'Anse-Au-Loup Makkovik Rigolet	Croque Flower's Cove Grandois Grey River La Poile McCallum Petite Forte Petites South East Bight Charlottetown Fox Harbour Mary's Harbour Paradise River Port Hope Simpson Postville
No. Of Sites	2	11	15
Annual Energy (kwh)	4,100,000	8,800,000	5,700,000
Benefits ($1980 Discounted)	3,200,000	8,300,000	6,800,000
Capital Cost Range ($1980)	2,000,000 to 2,900,000	8,000,000 to 11,000,000	12,000,000 to 15,000,000

It should be noted that this analysis is conducted from the electric utility or diesel plant operator perspective. The conclusions regarding the economic viability of potential sites are sensitive to assumptions on unit fuel costs, annual fuel price escalation rates and the discount rate. These assumptions regarding fuel prices, in particular, may not be as appropriate in 1982, given world oil market events and changes in Canadian energy policy, as when they were first formed for the site assessment study. In addition, an analysis performed from the national perspective, using fuel prices closer to international crude oil price levels, might produce somewhat favourable conclusions on site viability than those arrived at from the utility or diesel operator perspective.

The figures for annual energy can be compared with the total generation by the 40 remote diesel systems of 59 million kWh in 1977/78. Tentatively one can conclude that small-scale hydro development might reasonably displace 10 to 25 % of the total diesel generation.

A review of the cost, benefits and the influence of the characteristics of these developments suggests:

1. No development of less than about 50 kW is likely to be viable, because the scale is not economical and access and transmission costs are relatively high.
2. This in turn rules out any community diesel system with a peak demand of less than 50 kW.
3. Sites with a gross head of less than about 10 m are unlikely to be viable because a weir dam for the power development is too expensive.
4. Although the higher fuel costs in Labrador promote hydro development they are effectively counterbalanced by the lower runoff and more variable stream flow in this region.

RECOMMENDED SITE

An objective of the study was to examine in some detail one or more of the potential sites and to prepare simple engineering layouts and a complete estimate of construction cost, and finally, to propose one site for development as a demonstration project. The folowing criteria were used to select the site(s) for more detailed study from the 13 shown to be perhaps viable:

1. The best prospect of economic viability. At this stage, capital costs were speculative, so potential economic viability was very uncertain.
2. Maximum fuel savings; the larger schemes were preferred.
3. A budget of $1.1 million.
4. Reasonable access both to the site and to the community. As a demonstration project, the development should be readily accessible for observation.

Of the 13 sites, three satisfied all criteria reasonably well: Burgeo, L'Anse-au-Loup, and Roddickton. Each location was visited.

A comparison of the more relevant qualitative characteristics of the three sites, including a more detailed and accurate cost estimate based on an engineering layout was prepared. Roddickton was proposed as the site most suitable for development as a demonstration project. This choice was based primarily on the fact that Roddickton is considered to be reasonably representative of the potential sites, and to possess no particularly unusual (bad or good) characteristics. One potential disadvantage is that its marginal economic viability benefits and costs are approximately equal. However, this same comment can be applied to most of the potential development sites and it is these same sites that must be proven economical if small-scale hydro is to make any significant contribution in the province to display diesel-generated kWh.

This recommendation was agreed to by both Newfoundland and Labrador Hydro and the federal Department of Energy, Mines and Resources and the project was released for construction.

RODDICKTON PROJECT ECONOMIC EVALUATION

A preliminary analysis made with Roddickton Project actual cost is shown in Table 5. The project cost $2 882/kW to install at end of 1980. The annual capacity factor is approximately 40%. The average unit energy cost is 12.48 ¢/kWh assuming 14% discount rate and a 30 year life. The fuel cost at Roddickton diesel plant is 5.4 ¢/kWh in 1980. Under an assumption of long-term annual escalation rate of 10% in fuel price, the levelized unit fuel cost is 12.68 ¢/kWh. The total cost of the Roddickton mini-hydro project over 30 years will be equivalent to the value of fuel it displaced.

If a lower discount rate of 12% is used, the project could be economic over 30 years life but will take 20 years to breakeven. Assuming a projected international oil prices (long term domestic oil price at 75% of international price) is used as from national point of view, the Roddickton mini-hydro project will be economically attractive over its life under both 12% and 14% discount rates analysis, provided the assumptions on fuel price are valid. In the early years however the plant costs will exceed savings by more than 100% before taking into account the federal grant.

TABLE 5

RODDICKTON MINI-HYDRO ECONOMIC EVALUATION

Generating Capacity, kW	425	
Annual Generation, kWh/yr	1 500 000	
Capital Cost, 1980	$ 1 225 000	
Unit cost of Capacity Installed, $/kW	2 882	
Discount Rate	12%	14
[1]Annual Carrying Charge Factor,	13.41%	15.28
Annual Cost	$ 164 270	$ 187 180
Average Unit Energy Cost, ¢/kWh	10.95	12.48
Total Present Worth in 1980 of Annual Cost over 30 years	$ 1 323 250	$ 1 310 770
Diesel Fueld Cost in 1980, ¢/kWh	5.4	5.5
[2]Total Present Worth of Fuel Displaced over 30 years	$ 1 684 500	$ 1 331 400
Levelized Unit Fuel Costs, ¢/kWh	13.94	12.68
Benefit/Cost Ratio	1.27	1.02
Breakeven Years	20	29
[3]Benefit/cost Ratio Using Assumed International Oil Prices	1.69	1.35

Notes:
1. Based on 30 years economic life of the plant, O&M expenses at 1%, sinking fund depreciation.
2. Based on annual escalation rate of 10% in fuel prices.
3. Assumed long term domestic oil price at 75% of the international price.